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All correspondence relating to the publication of papers should be addressed to the editor, Abel Wolman, 2411 North Charles Street, Baltimore, Maryland.

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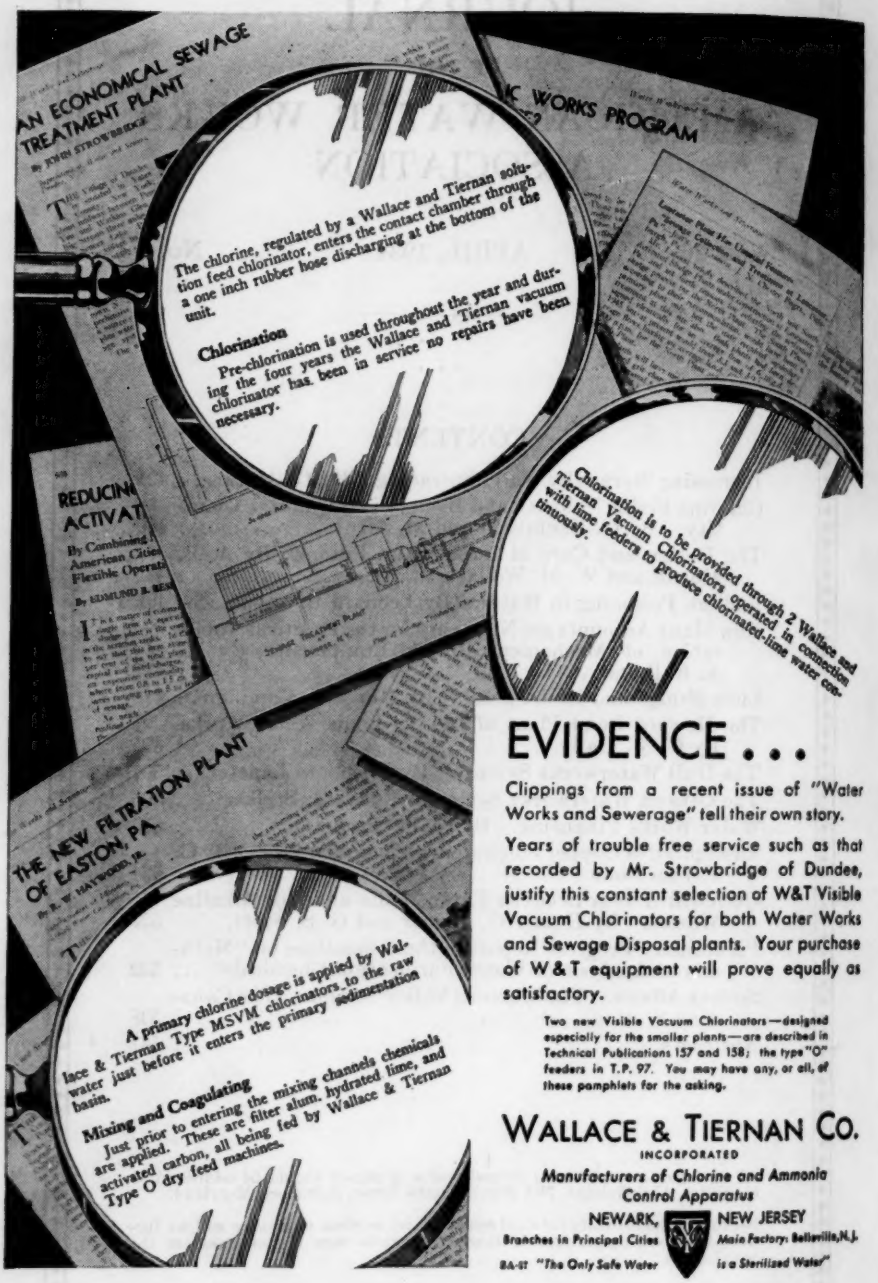
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IC WORKS PROGRAM
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INCREASING STORAGE BY WATER SPREADING

By D. A. Lane

(Assistant Engineer, Groundwater Development, Department of Water and Power, Los Angeles, Calif.)

The use of water spreading, or artificial replenishment of underground basins, is by no means of recent origin. Apparently the first actual spreading of water for this purpose was done by the Irvine Ranch Company from Santiago Creek in Orange County, about 1896.

There are four primary methods of groundwater artificial replenishment. The original method of spreading on the débris cones by means of ditches after the flood flows had passed and the water became clear, has become more efficient and a greater amount made available by the construction of flood control reservoirs. These reservoirs act as desilting basins and make not only a larger amount of water available, but also extend the period of operation, reducing the amount of land necessary for spreading. In many cases, this regulation makes it possible to handle the entire flow of the stream in the natural channel without the construction of works or the need of labor to control it.

In some basins, such as the San Fernando Valley, the natural groundwater is augmented by the spreading of so-called foreign water, such as the Owens River Aqueduct water. In other groundwater basins water spreading can only be accomplished by means of wells piercing the clay blankets which separate the various water-bearing stratas.

In some districts, such as that immediately adjacent to the coast

of Los Angeles County, in the future it will become necessary for all industrial consumers to use reclaimed sewage water, allowing their local groundwater to have a natural recovery by lack of demand.

There is no general rule or plan of water spreading that may be laid down as applicable to all groundwater basins. Each area must be taken as a separate problem and studied not only from the possibilities of water spreading, but also the effect on the groundwater table and the ability to recover the water so spread by those paying the cost of the operation.

During the past ten years, numerous water companies and agencies have carried on spreading of one type or another. However, there are little or no published data of sufficient accuracy to be of use to those studying the problem. In several instances, rates of percolation were of little or no interest to those carrying on the work, due to the fact that the area owned or controlled by them was more than sufficient to take care of the amount of water available.

In Southern California, the greatest problem confronting water users is sufficient storage to smooth out the seasonal fluctuations and insure a safe and adequate supply during those months of greatest demand. Surface reservoir sites are few in number and exceedingly expensive per acre foot of storage.

The Los Angeles problem

The City of Los Angeles, being dependent for the major portion of its supply from the Owens River Valley, must utilize every method possible to conserve the peak flow from this source.

As all feasible surface reservoirs have been constructed, it is only natural that the groundwater basin of the San Fernando Valley be operated to its maximum efficiency.

Due to the porous alluvial material composing the eastern portion of the valley, it is ideal as a groundwater storage basin. Being composed of granitic alluvium, there are no continuous clay blankets which might prevent the percolation of waters from the surface directly downward to the water table.

In 1924, a group of wells, with a capacity of 100 cubic feet per second, was drilled east and west across the center of this portion of the valley as an emergency supply. At the lower end of the valley is a series of diversion works, a part of which had been the original supply for the City previous to the construction of the Los Angeles Aqueduct and had been supplemented by the construction of wells

and galleries during subsequent years. These works guarantee the extraction of all waters, both surface and subterranean, attempting to leave the valley by the natural drainage channel of the Los Angeles River.

It was proposed to store a part of the winter flow of the Owens Valley Aqueduct within this easterly portion of the valley and recover it either at the emergency plant in the central portion of the valley, known as the North Hollywood Plant, or at a later date in the lower diversion works from Griffith Park to the Elysian Narrows.

The problem to be solved was to find an area suitable for water spreading where the cost of land and construction of trunk line supply would not be prohibitive, and at the same time be at a sufficient distance from the North Hollywood Plant that water spread during the winter months might become available during the following summer peak demand.

As a result of an investigation of all existing spreading operations, it was concluded that the economical method of spreading in the San Fernando Valley would be by means of basins systematically cleaned and operated. With this in mind, a series of test basins were constructed and a detailed test carried over a period of two years.

From studies made at the test basins, it was found that rates of percolation in this area vary from a minimum of 3.0 to a maximum of 10.0 acre feet per acre per day for the net area exposed. Over a 33-day period the average percolation was 6.29 feet per acre per day, and for a 53-day period 3.86 feet per day. The basins were cleaned only between each period. For the gross area, which includes spoil banks and roads, a mean flow of 1.0 cubic foot per second per acre was apparently a safe basis for estimate for operation of a major spreading grounds.

To observe the effect of the waters spread on the water table, a total of 30 wells were measured. A correlation of the maximum and minimum spread in all basins, and the rise and fall of one of the wells at the test basins, showed an average lag of five days, or a rate of 20 feet per day vertically, as the water table was 100 feet below the ground surface. The area on which the effect of spreading 1300 acre feet could be traced was 1800 acres. The maximum rise was at the well immediately adjacent to the test area, with 8.75 feet during a peak spreading of 11.0 second feet.

Velocities, as indicated by the length of time required for wells to reach their maximum elevation from the time spreading started,

using an average of six wells, was from 3.0 to 4.4 miles per year, with a mean of 3.68 miles per year for an average slope of 2.61 feet per 1000 feet.

With the data made available by the above tests, a total of 183 acres of land was purchased in the Big Tujunga Wash, approximately two and one-half miles below San Fernando Road. About 15 acres of good spreading area is lost due to the main flood channel of the Big Tujunga Wash. The property is paralleled on the south by the main 72-inch trunk line leading from the Lower San Fernando Reservoir into the City, thus the only expense for pipe line is for distribution within the spreading area.

The strippings of each basin were used to construct the berms between basins, and the remainder of the soil was used to construct the roads between each series of basins.

All construction work was done by means of caterpillars equipped with bulldozers or McMillan graders. In the construction of the berms the bulldozer was found to be the most valuable piece of equipment, as those berms constructed with the grader showed a tendency to wash out when subjected to a head of water.

Hand labor was used in the clearing of the land and the smoothing down of the berms.

Trunk lines consist of secondhand 30- and 36-inch riveted pipe. Each basin is served by a 6-inch line controlled at the main by a 6-inch valve. Within the basin two parallel sections of 6-inch diameter pipe, with slots cut in them, extend out a distance of approximately 100 feet from the end of the basin.

The completed cost per acre on the gross area for that portion under operation is $1269. This consists of $423 for land purchase, $506 for pipe lines and valves, and $340 for basin and road construction.

During the period of operation the crew is composed of four men, three regular operators and a relief man. The day is divided into three shifts of eight hours each.

All basins are maintained at a uniform depth of water of approximately 0.50 feet. This prevents wave action from cutting into the side walls of the basins during a sudden windstorm.

The operating schedule calls for the hourly reading of the pressure on the main trunk line passing the property, the trunk supply line and staff gauge readings on each basin in operation. A light work car is furnished the operating crew as it is essential that rapid trans-

portation be available at all times should a break occur at the most distant point of the property, which is over one-half mile from the control valves.

The careful observation of pressure is necessary due to the fact that the supply line carries a pressure of from 80 to 115 pounds, while a safe pressure on those lines within the spreading grounds is about 45 pounds. Notwithstanding a pressure control valve has been installed, it is considered an economical precaution to have these hourly manual readings made.

As a result of the test basin operation, it was thought it would be necessary to clean the surface of all basins at least every thirty days.

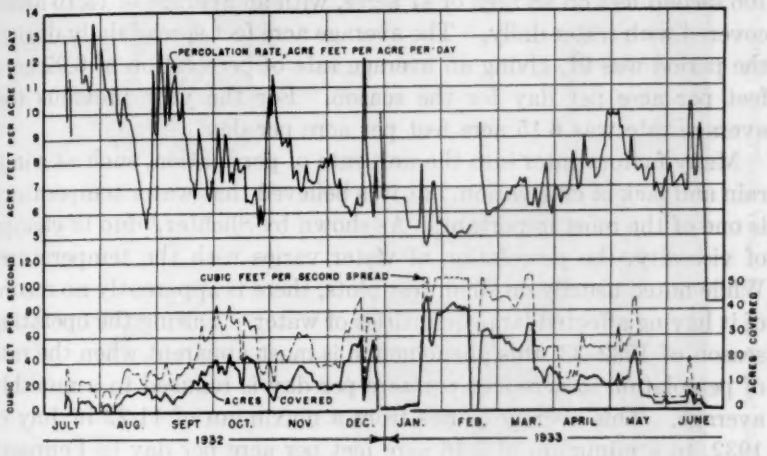

FIG. 1. CITY OF LOS ANGELES. DIAGRAM SHOWING AREA COVERED, QUANTITY SPREAD AND RATE OF PERCOLATION AT TUJUNGA SPREADING GROUNDS, 1932-33

With this in view, the first 20 acres of basins constructed were carefully leveled to a variation of less than one-tenth of a foot. During the first year, various methods of destroying the surface crust were tried. The most satisfactory method found was to cultivate with a spring tooth harrow at a time when the basin had been allowed to dry to a point where it did not form a muck nor break into clods.

The effect of this cultivation is to throw the bottom of the basin into ridges and furrows with a difference of elevation of 0.20 to 0.30 feet The silt, which is stirred up by wave action, settles to the bottom of the furrow, leaving the crest of the ridge free for percola-

tion. The suggestion has been made that eventually this will cause a sealing off of the basins. Such has not been the case after two years of operation. Soil samples taken at the same point before and after the two years' operation show that the soil, both at the surface and at lower depths, contains less fine material than when spreading was started. This cultivation work is done by means of a small caterpillar tractor and operated by the relief man. The length of operating time lost for cultivation varies from 8 to 24 hours per basin.

The spreading period for the past season extended from July 12, 1932, to June 20, 1933. During the year a total of 31,298 acre feet of water was handled at this works. The maximum flow spread was 106 second feet on an area of 47 acres, with an average of 13.16 acres covered with water daily. The average acre feet spread daily during the period was 91, giving an average rate of percolation of 6.92 acre feet per acre per day for the season. For the year previous the average rate was 6.15 acre feet per acre per day.

Many factors enter into the unit rate of percolation, such as wind, rain and lack of cultivation, but it is believed that water temperature is one of the most important. As shown by Slichter,[1] due to change of viscosity, the percolation of water varies with the temperature. While noted usually on small test plots, there is apparently no record of it having affected large quantities of water. During the operating season of 1932–33, this phenomenon is most apparent when the rate of percolation in acre feet per acre per day is reduced to a monthly average. This average varies from a maximum of 11.22 in July of 1932, to a minimum of 5.46 acre feet per acre per day in February of 1933. There is a decrease from the July maximum to the February minimum, and then a gradual increase up to the following May and June, which closely followed the water temperature as determined by a recording liquid thermometer.

It was observed that each time a basin was shut off and all water allowed to percolate out, if only for an hour, the unit rate of percolation decreased. This proved that intermittent operation of basins, as advocated by some engineers, will not permit the maximum rates of percolation.

To observe better the action of the spreading on the water table, a 20-inch diameter well, with a depth of 450 feet, was drilled adjacent to the works. Prior to spreading, the water table stood 174 feet

[1] Slichter, Charles S., The Motion of Underground Waters, Water Supply Paper No. 140, U. S. Geological Survey, 1905.

FIG. 2. CITY OF LOS ANGELES, TUJUNGA SPREADING GROUNDS, MARCH 27, 1933
Spreading 47 sec. ft.; area covered 13.05 acres. (Photographed by 40th Division Aviation, California National Guard.)

below the ground surface. During the season of 1932–33, the water table rose to a depth of 153 feet below the ground surface, an artificial rise of 21 feet.

During the 1932–33 season, the cost of spreading was as follows:

	dollars
Capital investment	0.16
Land investment	0.12
Operation and maintenance charges	0.38
Total	0.66

As all of the land, and a part of the capital investment, is for a total capacity of 200 acre feet, the unit costs on these items will naturally be reduced when the works are operating at full capacity.

In that portion of the works under operation at the present time, the net spreading area is 80 percent of the gross area. Under other methods of spreading, the net area is usually about 25 percent of the gross area. The increased cost of the basin method is, therefore, justified by its increased efficiency.

The average annual charges per acre foot of storage on four surface reservoirs in the San Fernando Valley is $5.70 for capital investment and $3.23 for operation and maintenance, a total of $8.93.

Assuming all water spread had to be pumped from the plant with the greatest lift, the total annual charges on this type of storage would be $3.36 per acre foot.

In addition to the operation of the basin spreading works, the Department of Water and Power annually spreads several thousand acre feet of water in the San Fernando Valley by means of abandoned gravel pits. The capacity of most of these pits is limited only by the size of the trunk line supplying them. On the larger pits unit rates of percolation are impossible to obtain. However, on one of the smaller pits observation showed a unit rate of 24 acre feet per acre per day. This rate continued over a period in excess of 30 days and at the end of the period showed no change, regardless of the height of water in the pit.

By the use of these pits, which are for the most part located in the upper portion of the valley most distant from the points of diversion, the water may be stored according to the character of the season. During the fall, if the indications are for a wet season, most of the spreading is concentrated in those pits most distant from the diversion works. If there is light rainfall during the fall and spreading water is available only during the late spring, all spreading is con-

centrated on those pits and the basins nearest to the points of diversion, thus making the water available during the current summer season.

Using the wet year of 1922 as a minimum, the average dry period capacity of this easterly portion of the San Fernando Valley storage basin, is 150,000 acre feet. This is more than twice the capacity of the largest surface reservoir in the City's system, which is located in the Owens Valley, and more than seven times the capacity of the largest reservoir in the Metropolitan area at the present time.

By means of the observation of several hundred wells, the location of the water so spread may be determined and closely followed throughout the year.

In the future, the most important contributions to the water supply of semi-arid areas will be the intensive development and use of groundwater storage basins by means of water spreading.

(*Presented before the California Section meeting, October 26, 1933.*)

CHLORINE FIXING VELOCITY AND BACTERICIDAL CHLORINE QUANTITY

By G. Nachtigall

(Chief Chemist, Division of Water Supply, State Institute of Hygiene, Hamburg, Germany)

AND

M. Ali

(Professor Agrégé, Medical Faculty, University of Istanbul, Turkey)

The maintenance of 0.10 to 0.20 p.p.m. residual chlorine, detectable by the ortholidine test 10 to 20 minutes after chlorine application, insures the continuous and effective removal of disease-producing bacteria.

This control serves a two-fold purpose: it prevents over-treatment of the water, and it indicates that chlorine, sufficient for complete bactericidal effect, has been applied (1). With ammonia chlorine treatment or with the ordinary chlorination of water, naturally containing ammonia or albuminoid ammonia, higher residual chlorine values and longer contact periods should, as a general rule (2), be allowed. In such cases, the chlorine "values" should be differentiated by estimations with ortho-tolidine and methyl-orange considered together (3) and they should be checked against bacterial analyses (4).

The method of Bunau-Varilla (5) differs from this approved "axiom" in that it disregards the chlorine-demand of the water and attributes the greatest importance to a vigorous agitation accompanying the chlorine application. By this agitation, Bunau-Varilla reports being able to sterilize a clear water with 0.10 p.p.m. chlorine, and, slightly turbid water with 0.20 p.p.m. Owing to the action of chlorine on the organic substances present in the water, invisible bactericidal rays are supposed to arise. Bunau-Varilla's experiments, however, are still not convincing and it would seem that the strong agitation produces no other effect than a more thorough mixing of the chlorine with the water (6, 7).

Investigation of the method of Bunau-Varilla shows that one can

disinfect certain waters, by applying only part of the known chlorine demand, *even without agitation* (7). This is probably due to the varying quality of the waters themselves and to the fact that any unusual behavior in chlorination might not be shown by the routine determination of chlorine requirement. All methods (8) used to determine the chlorine-demand of a body of water strive for the same end, namely, to find the smallest quantity of active chlorine that is fixed within a certain time. Sufficient attention, however, has not been paid to the manner in which this chlorine is diminished within this fixed period of time. It is not essential that the velocity with which an amount of chlorine is fixed, and then becomes ineffective, should be the same in two different bodies of water, even though both have the same chlorine-demand. This fact may be determined by testing for the quantity of chlorine, residual after every 15 seconds. When the chlorine amounts, determined by tests, are plotted graphically, one obtains the curve of the "chlorine-fixing-velocity." If one of the two waters with the same chlorine-demand shows a steep curve, and the other, a gradual one, indicating a slowly diminishing chlorine amount, it is probable that with the same quantity of chlorine in the second water, better disinfection can be obtained because the bacteria remain longer in a more concentrated solution of chlorine.

METHOD OF DETERMINING CHLORINE DEMAND

For the chlorine determination, we have made use of the orthotolidine method because of its extreme sensitivity, and, because it is the most reliable index of effective chlorination. With this reagent (9), we could make a determination in 25 cc. with an error of ± 0.01 p.p.m.; at which rate the real error is only ± 0.00025 milligrams of chlorine. Only 0.08 to 0.10 p.p.m. chlorine can be detected by the starch-iodide method. Alpha-naphtholflavone (10), used instead of starch in the iodide test, gives a rose color with as little 0.03 p.p.m. chlorine, but this accuracy occurs only rarely if a chlorine solution is titrated back with sodium thiosulphate. A great advantage of the tolidine test, furthermore, is the fact that this colorimetric determination can be used in the opposite direction; that is, one adds to the tolidine indicator (any distilled water and 1 cc. reagent in a 100 cc. Nessler tube) so much of the chlorinated sample until a true yellow color arises. The applied amount of chlorinated water is noted and, after filling up with distilled water to 100 cc., the color compared with permanent chlorine standards in similar Nessler tubes.

Many samples of distilled water were examined and we found their chlorine-absorptive-capacity extremely variable (chlorine demand between 0.06 and 0.50 p.p.m.). This explains the fact that many authors assign nearly no chlorine-absorptive-capacity to distilled water, while others compare it with tap water. An extremely pure distilled water was necessary for the solutions used in the experiments described below. We required a solvent (distilled water) with a chlorine capacity as low as possible, and about nearly equal in all experiments. The manufacturing of double-distilled water, previously purified by permanganate and sulphuric acid, was too costly and very impractical to obtain in the great quantities needed for the experiments. Therefore the water was treated in this way:

Five-litres bottles were filled with about 3 litres of distilled water and then freshly made chlorine water was added until about 0.30 to 0.40 p.p.m. chlorine was present in excess. (The first time we used 4 p.p.m., but this quantity was too great.) These bottles, covered with cups to protect them against dust, were left for, at least, 48 hours at room temperature. After this time, the chlorine still present was removed by boiling. Distilled water thus produced has a very small chlorine demand. Holwerda, in the tropics, produced distilled water for similar experiments by exposing his experimental solutions to the sunlight. We, in Hamburg, lack sunshine sufficient for this treatment. Ultra violet light does the same as sunlight and in some respects is preferable to boiling but it was too expensive.[1]

Distilled water, so prepared, is referred to herein as: "purified distilled water." This purified distilled water retains the power to form

[1] A remarkable fact, in this connection, is: if the distilled water is tested with tolidine, before it is boiled, it, at first, shows a very low content of active chlorine; but the yellow color increases as the sample is left for a time. For example: a distilled water not reacting directly with Nessler's reagent and having a permanganate consumption of 1 p.p.m. was mixed with 3.0 p.p.m. chlorine and left for 4 days. Immediately after tolidine was added there was no color; after 1½ minutes 0.05 p.p.m.; after 4 minutes, 0.10; after 10 minutes, 0.30; after 22 minutes 0.60 p.p.m. and then it remained constant. These chlorine compounds, from which the chlorine is only slowly released by the acid tolidine reagent, seem to be complex organic substances with NH_2- or NH groups. These chlorine compounds are indicated neither by the acid starch iodide test, by the acetic acid alpha-naphthoflavone-iodide test, nor by the methyl-orange. It is possible that the yellow color was caused by other oxidizing substances, but this is not probable since such oxidizing substances were not detectable in the water before chlorination. By boiling out, this chlorine can be removed.

such chlorine compounds, which, when mixed with tolidine, will again slowly deliver up "free" chlorine, although naturally not in such great quantities as in the example mentioned above.

The determination of chlorine with tolidine has a value as a means of comparison. The yellow tolidine color is a product of oxidation. The chlorine consumption in waters is also preponderantly a process of oxidation. The velocity of tolidine oxidation can be compared with that of other substances. It is not necessary that the chemical process with other substances being compared should be solely that of oxidation. The value of the comparison remains, since, in the following experiments, it is our aim to study those factors which render chlorine ineffective. For this reason we take no notice of the nature of the chemical processes—they are simply characterized as chlorine-tolidine, chlorine-peptone, etc. Likewise, we speak of "a great affinity for chlorine" when a certain solution very quickly renders chlorine ineffective, even though no real chlorine compound is formed.

A comparison of the affinity of tolidine for chlorine, in the presence of other substances, gives the following groups:

Group 1. Substances with an extremely great affinity for chlorine which

(a) are able to decolorize the yellow color of the chlorine-tolidine compound (in reality these substances have great power of reduction)

(b) can prevent, by their presence, the formation of the chlorine-tolidine compound (the appearance of yellow color)

Sodium thiosulphate, for instance, belongs to group (a), peptone to group (b).

The determination of substances of Group 1 (a) can be made in the following way: A chlorine-tolidine solution, with known color intensity, is made—for example 0.40 p.p.m. This solution is mixed with the water to be examined, or with a known solution of a substance in purified distilled water (for example, half diluted). If the color intensity is half as great when the solution is diluted to half strength (0.20 p.p.m.) then no substances belonging to Group 1 (a) were present. We have only to consider that, if the solution is alkalized by the added substance, the color disappears; the reaction must be acid to make the yellow color appear. The added water, therefore, must be mixed with a corresponding amount of HCl-tolidine reagent.

The determination of substances in Group 1(b) is as follows: When the tolidine reagent and a known chlorine amount are added to the water, or solution of a certain substance, the color, sometimes, does not correspond to the added chlorine amount, but to a lesser one. The difference, then, corresponds to substances of Group 1 (b).

Group 2. The substances of this group can neither decolorize the yellow chlorine-tolidine color nor prevent its development, having, therefore, less affinity for chlorine than for tolidine. Otherwise, they combine with chlorine extremely rapidly and make it ineffectual. These substances are determined as follows: A chlorine amount exactly adjusted is added to the water which is to be tested; tolidine reagent is added precisely 15 seconds after and the color, which now develops, is compared with standards. The difference corresponds to substances of Group 2. (Fifteen seconds were used as standard for these experiments.)

Group 3. This group consists of the slowly reacting substances. They are characterized by the form of the curve plotted according to the chlorine amounts, as determined every half minute. The determination of the second group, therefore, marks the beginning of this curve. In this way one gets curves, the forms of which are constant and characteristic for certain substances. The forms of these curves are described below.

The substances making up these groups must not be accepted as exactly determined nor as always fixing the same amount of chlorine. Generally, the bound chlorine amount depends, rather, on the quantity of chlorine added and is, therefore, always the same by checked determinations. When we speak of "substances," therefore, only those qualities of the substances are meant which are able, under above conditions of determination, to render the active chlorine ineffectual. Many are substances chemically definable as thiosulphate, phenol (Group 1 (a)), arsenous acid (Group 2), etc. With such substances, the quantity of chlorine which is bound, or, more rightly, which is made ineffective, depends probably, not on the initial chlorine dose; and their classification is doubtless clear. In the case of most substances, on the other hand, only a part of the chlorine-demand holds for one or the other groups. For instance, when 1.43 milligrams of chlorine are added to 1 gram gelatin in 1 litre purified distilled water, this chlorine can no longer be detected even though tolidine is added ever so quickly (Group 2). On the other hand, when tolidine is added first and then the chlorine, 0.88 p.p.m. can be accounted for

(Group 1 (b)). Owing to this fact, the gelatin may be assigned neither wholly to Group 2 nor to Group 1 (b).

The classifications of these substances should not be thought of as "absolute," but should simply give an idea of the behavior of a certain chlorine quantity in a known solution.

In these determinations, tolidine is arbitrarily chosen as the comparison-factor. It would be desirable to make these determinations with other reagents, also, but there is no method which is so practicable as tolidine. (With benzidine (13), for instance, a fairly rapid bleaching occurs, as, also occurs in an acid medium. Methyl-orange (12) is decolorized in acid solutions only by the so-called "true free chlorine." Ferrocyanide of potassium, which reacts at pH 6–7 with true free chlorine and with NH Cl_2, but not with NH_2Cl and NCl_3, is not sensitive enough) (11.) But, by means of the tolidine reagent, one can, in most cases, estimate the "loosely fixed chlorine." This "loosely fixed chlorine" develops the yellow color more slowly than "true free chlorine" and acts as a bactericide, more or less slowly, according to the substance by which it is bound.

PRE-EXPERIMENTS

Considered from the point of view of the above-classified groups, it is not necessary that two samples of water with the same chlorine-demand should be identical. One water, for instance, may contain none of Group 1, a little of Group 2, and may show a proportionally level "curve;" whereas the other water may have much of Group 1 and Group 2 and, therefore, show a very steep "curve." In that case, it stands to reason, that the same chlorine amount, applied to the two samples, having the same chlorine demand, must act more effectively against the first sample than against the second. Then the chlorine, that is bound by substances like thiosulphate, can have no bactericidal action, whatsoever. When substances of Group 2 are present, the chlorine should be able to produce a bactericidal effect only in such cases where the bacteria have a greater chlorine-fixing velocity than these substances. But that is not the fact, as the experiments presented below indicate. Only that chlorine is able to disinfect, which remains after the first and second groups are substracted. The quantity of this chlorine, in the above example, must be much greater for the first water than for the second. Such cases are not only conceivable, but are actually known to exist. It is known, for instance, that phenol (Group 1) disturbs chlorination;

that humus-waters (Group 2) are difficult to disinfect. Therefore, merely the determination of chlorine-demand cannot be sufficient for the determination of the disinfection-chlorine amount. To con-

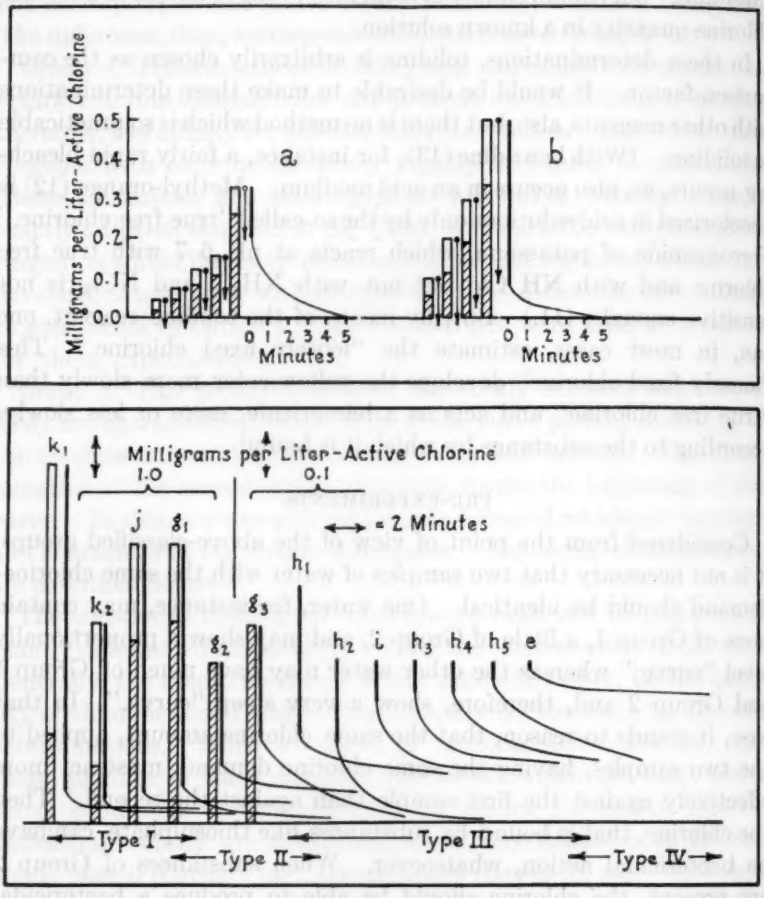

FIG. 1. The columns correspond to the applied chlorine amount, and their clear part to the group 1. The verticals and the heavy initialed part of the curves show the group 2. The continuations indicate group 3. a = tap water. b = tap water + 1.5 percent peat extract. e = purified distilled water. g_1 = dry albumen, trading ware; 0.02 percent. g_2 = asparagin; 0.1 percent. g_3 = white of new-laid eggs; 0.02 percent. h_1 = maltose; 1.0 percent. h_2 = lactose; 1.0 percent. h_3 = cane sugar; 1.0 percent. h_4 = grape sugar; 1.0 percent. h_5 = mannite; 1.0 percent. i = agar-agar; 0.1 percent. j = gelatin; 0.03 percent. k_1 = gelatin-nutrient-medium; 0.6 percent. k_2 = meat-water-agar; 0.4 percent.

firm this supposition, solutions of various group-types, with which to start bacteriological experiments, must be made. The following pre-experiments intend, therefore, not only, to disclose the behavior of different substances, but also, to obtain material for the main experiment.

The results of these experiments can be mentioned only briefly, but the most important of them are shown in figures 1 and 2, so that their reading allows for further interpretation. For these, and likewise all other experiments, newly made chlorine water was always used.

a) Hamburg tap water: Group 1 (a): a few unsteady: Group 1 (b): the absolute quantity increases with the applied chlorine amount, but in proportion to the total chlorine quantity. It is greater with smaller quantities. Group 2: the values for several chlorine quantities are represented in figure 1. The absolute quantity increases with chlorine, added at any rate, but, in ratio, it is greater with smaller quantities. Group 3: Curve *a* in figure 1.

b) Hamburg tap water with 1.5 percent peat extract: Addition of peat extract multiplies, above all, the Group 1 and Group 2; the curve, therefore rises sharply.

c) Distilled water, "commercial": the values are extremely variable. The chlorine demand is 0.06 to 0.50 p.p.m. (In one sample with 0.56 p.p.m. chlorine applied, in the second group, the chlorine demand was 0.42 p.p.m. which is much more than with tap water.) This unsteady behavior of distilled water is an important source of errors in chlorination experiments.

d) Physiological solution of sodium chloride: reacts as the distilled water used for the solution.

e) Purified distilled water: Group 2: chlorine demand is about 0.01 to 0.02, or 0.05 to 0.08 p.p.m., if 0.15 or 0.50 p.p.m. chlorine, respectively, is added (see curve in fig. 1).

f) Organic acids: most of these react as the purified distilled water used for solution.

g) Albuminous substances: Very great chlorine-fixing power with decided presence of Group 2, therefore, show a very steep curve, at beginning (fig. 1, *g* 1–*g* 3).

h) Kinds of sugar: Chlorine-fixing power is proportionally small; there is almost no Group 1, a moderate amount of Group 2; the curve is falling.

i) Agar-agar: as sugar.

j) Gelatin: almost only Group 2; very steeply falling curve at beginning.

k) Nutrient media: Very great chlorine-fixing power due, primarily, to peptone. Peptone increases very intensively the Groups 1 and 2. This is an important source of errors in chlorination experiments, inasmuch as small quantities of nutritive substratum may get into the experimental fluid by the addition of bacteria.

l) Bacteria: Arrangement of experiment: B. coli from eighteen-hour-agar culture, suspended in distilled water, filtered and washed 3 times. The suspension used in the experiments had a chlorine-demand of about 0.40 p.p.m. which is nearly like tap water. Group 1, none; Group 2, very small. The largest amount of chlorine is fixed during the first minute. The chlorine-fixing velocity of bacteria, therefore, is not so great as that of substances with a large amount of Group 2, but it is considerably greater than that of tap water. The chlorine-fixing curve of bacteria has the character of an absorption curve. Interpreting the chlorine-fixing-velocity curves of bacteria and tap water, determined by supplying double their respective chlorine-demands (fig. 2), bacteria would seem to fix the chlorine with greater velocity, but, actually, the chlorine disappears first in tap water. In bacteria suspension, the chlorine, after decreasing rapidly, remains detectable for days and is pretty constant. This is of considerable importance.

From these experiments, one may differentiate 4 types of curves:

Type 1: Curves with extremely steep beginnings and then rather horizontal courses. Solutions of substances belonging to Group 1 and 2 yield such curves. In these curves, the chlorine-consumption, indicated, is very great in proportion to the amounts of these substances really present, and increases greatly with the addition of more chlorine. Consequently, a great residual chlorine excess cannot be attained even when a multiple of the chlorine-demand is added. The curves of peptone, gelatin, nutritive substrata, etc. illustrate this (fig. 1).

Type 2: Curves of substances with few or none of Group 1, much of Group 2 and some of Group 3. The curve decreases, immediately, in the beginning with the application of about 50 to 70 percent of the chlorine-demand, but later it becomes more level. In this type, an excess can be obtained by adding a greater chlorine dose than the chlorine-demand requires. Albuminous substances, for instance, belong to this type.

Type 3: Curves of solutions with few of Group 2 and very large quantities of Group 3. The curve decreases, initially, only a little. Residual chlorine excess can be attained by applying an amount of chlorine which exceeds the chlorine-demand only by a little. Kinds of sugar, for instance, belong here.

Type 4: Curves of solutions having practically no chlorine-fixing power as, for example, purified distilled water, or, substances, unable to fix active chlorine, in solution of purified distilled water. (Urea, if this is estimated with tolidine (*14*).)

These experiments were carried out at room temperature; at higher temperatures, the curves become steeper so that one type nearly approaches, in character, the previous type.

MAIN-EXPERIMENTS

Considering that B. coli has a curve corresponding to Type 2, theoretically, what are the chances of bacteria being affected by chlorine in the different media? In Type 1, the chlorine concentration decreases immediately, and the bacteria, therefore, are, from the first, in a solution almost free of chlorine. Here, the chances of the bacteria being affected by chlorine are approximately zero.

In order to substantiate these hypotheses, which developed as results of the pre-experiments, 3 substances whose solutions belong to 3 different types, were chosen, as follows:

1. *Gelatin:* experimental solution: 0.3 grams in 1000 cc. purified distilled water (fig. 1 *j*).
2. *White of new laid eggs:* experimental solution: 1:5,000 (fig. 1 *g*3).
3. *Grape sugar:* experimental solution: 10:1000 (fig. 1 *h*4)

Experiments with Type 4 were not carried out, since that would have neither theoretical nor practical value. Chlorine solution, newly prepared from chlorine gas, in purified distilled water, was added. This was checked just before use with N/100 sodium thiosulphate. Coli were incubated eighteen hours upon agar culture medium, suspended in distilled water, filtered and washed 3 times. The B. coli content was adjusted to a concentration of approximately 300,000 per cc. in all solutions prior to the addition of chlorine. The results of this experiment are given in table 1.

With Type 2, on the contrary, a sufficient bactericidal effect is obtained with application of only 2:3 chlorine-demand; and with Type 3, bactericidal effect is obtained when only 1:6 the chlorine-demand has been applied.

These experiments, with precisely determined synthetic solutions, serve only for the theoretical discussion of the question. Nevertheless, it is to be considered as proved that the present assumption that chlorine-demand, plus 0.10 or 0.20 p.p.m., is sufficient for disinfection is only partially true. It holds, probably, for water belonging to Type 2 and for waters showing their curves displaced to Type 1. On the other hand, displacement to Type 3 facilitates the chlorine efficacy so that less chlorine is sufficient for these waters than their chlorine-demands indicate.

TABLE 1

RATIO OF CHLORINE APPLIED TO CHLORINE DEMAND	TYPE 1, GELATIN 0.03 PER CENT		TYPE 2, ALBUMIN 0.02 PER CENT		TYPE 3, GRAPE SUGAR 1 PER CENT	
	B. coli remaining per cc.	Residual chlorine p.p.m.	B. coli remaining per cc.	Residual chlorine p.p.m.	B. coli remaining per cc.	Residual chlorine p.p.m.
	5 minutes after chlorination		5 minutes after chlorination		5 minutes after chlorination	
1:6	∞	0	∞	0	14	0
1:3	∞	0	Nearly ∞	0	9	0
1:2	∞	0	About 500	0	0	0
2:3	∞	0	14	0	2	0
5:6	∞	0	6	0	0	0
1	∞	Trace	3	Trace	0	Trace
2	∞	0 02	0	0.05	—	—
3	∞	0 05	—	—	—	—
4	∞	0 05	—	—	—	—

These experiments, often repeated, thoroughly substantiate the theoretical considerations. With Type 1, no bactericidal effect can be obtained, even by supplying many times the chlorine-demand.

Natural waters, from different territories, must yet be examined, of course. The same body of water can show seasonal changes in regard to the above groups and types. There is, even, no necessity for these changes to affect, considerably, the chlorine-demand. If the chlorine dosage should be adjusted by "chlorine-demand plus 0.10 p.p.m." without a controlled chlorine residuum, B. coli may survive. Contrarily, the desired disinfection can, often, be obtained by supplying a smaller quantity of chlorine than corresponds to the chlorine-demand. Folpmers (6), for instance, has, for some time, chlorinated the Rotterdam water supply with a constant chlorine amount, although the chlorine-demand frequently exceeded this

amount; and he has always obtained sufficient disinfection thereby. Consequently, water examination should be highly desirable, in order to determine whether, according to its organic contents, too little or too much chlorine is being applied for adequate disinfection.

In the following, an attempt is made to characterize, in numerical values, the different types of waters. For this calculation, the

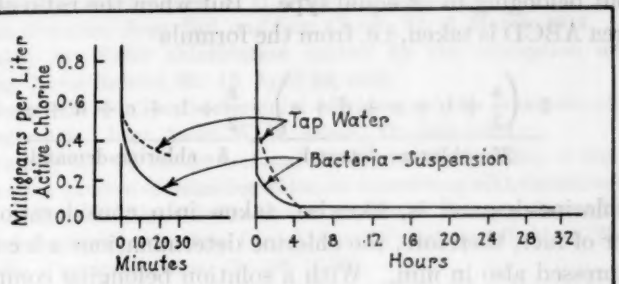

FIGURE 2

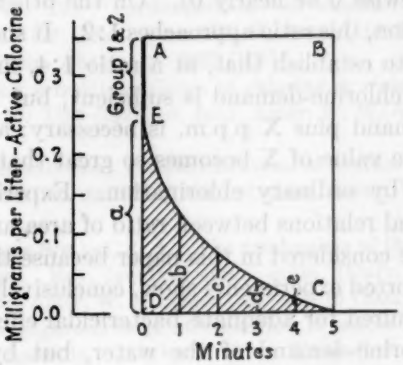

FIGURE 3

FIGS. 2-3

hatched area in figure 3 serves as a basis if one minute is considered as 5 mm. as abscissa and the chlorine amount of 0.01 p.p.m. with 1 mm. as ordinate. In figure 3, the chlorine-demand is 0.35 p.p.m. and the Groups 1 and 2 together 0.10 p.p.m. The hatched area CDE can be computed from the chlorine determinations made every minute by the formula:

$$5 \cdot \left(\frac{a}{2} + b + c + d + e \right) \text{mm}^2$$

For solutions, or waters of Type 1, this area should be very small, but becomes greater the more the curve approaches that of Type 3. The larger this area, therefore, the better the bactericidal effect. But since 5 mm. for 1 minute and 1 mm. for 0.01 p.p.m. chlorine are arbitrarily chosen for calculation, area CDE, expressed in quadrate mm., can be equal to two waters with different chlorine-demands without belonging to an equal type. But when the ratio of CDE to the area ABCD is taken, i.e. from the formula

$$\frac{5 \cdot \left(\frac{a}{2} + b + c + d + e\right)}{25 \cdot \text{chlorine-demand}} = \frac{\frac{a}{2} + b + c + d + e}{5 \cdot \text{chlorine-demand}}$$

the chlorine-demand is, likewise, taken into consideration. As a matter of fact, therefore, the chlorine determinations a b c etc. must be expressed also in mm. With a solution belonging completely to Type 1, the value of this fraction will approach zero (the bactericidal effect is likewise 0 or nearly 0). On the other hand, with an ideal type 3-solution, this ratio approaches 1:2. It should then, eventually, be possible to establish that, at a ratio 1:4, for instance, supplying part of the chlorine-demand is sufficient; but that, at a ratio 1:10, chlorine-demand plus X p.p.m. is necessary; and finally, at a ratio of 1:100, the value of X becomes so great that such a water cannot be purified by ordinary chlorination. Experiments, to determine the numerical relations between ratio of area and bactericidal effect, could not be considered in this paper because they were interrupted. But the reported experiments show, conclusively, that the amount of chlorine required for adequate bactericidal effect, is not determined by the chlorine-demand of the water, but by the velocity of its chlorine-absorption.

CONCLUSIONS

1. The chlorine quantity required for the disinfection of a water or solution is not always equal to the chlorine-demand plus 0.1 or 0.2 p.p.m., but depends upon the velocity of the chlorine-absorption.

2. This velocity can be determined with hydrochloric acid, orthotolidine reagent, and solutions can be grouped according to this velocity.

3. According to their types, many waters or solutions cannot be sterilized even with a chlorine quantity much greater than their

chlorine-demand, whereas, others can be sterilized with a chlorine quantity corresponding to only a fraction of their chlorine-demands.

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THE DESIGN AND CARE OF RAPID-SAND FILTERS

By A. B. Morrill

(Assistant Engineer of Filtration, Detroit, Mich.)

AND

W. M. Wallace

(Superintendent of Filtration, Detroit, Mich.)

At the risk of bringing down the wrath of some sanitarians, it will be stated that the real purpose of rapid-sand filtration is to remove turbidity, odor, taste and color from water. It is not to remove bacteria, although the process actually does remove a large proportion of those present. If the standards of removal of turbidity are as rigid as they should be, the removal of bacteria will be correspondingly high, so that the cost and difficulty of the later sterilization will be decreased. Under most conditions, however, if the filters remove practically all of the turbidity, odor, taste and color from the water, they have done all that should be expected of them and any further disinfection that may be necessary should be accomplished by other means.

DESIGN OF FILTERS

One of the first and simplest elements of the design of a filter is its shape. All the early filters were round, a shape that was appropriate because they were constructed in wooden tubs and rotating devices were used for cleaning them. As larger filters were built and as the art of reinforced concrete construction developed, the advantages of concrete became so obvious that its use for filter construction is now all but universal. The difficulty of forming curved surfaces in concrete and the economy of space that results from the use of rectangular units caused these to be generally adopted. The relative length of the sides is a matter of economy in construction cost. If, as is usually the case, the filters are ranged along one or both sides of an operating gallery, it is usually more economical to make the length of the side adjoining the gallery less than that of the sides at right angles to the

gallery. This results in a shorter gallery and a decrease in all the costs which go with it.

Assuming a plant of any given total nominal capacity, the number of filter units provided has an important effect on the cost and the success of operation. Too small a number of units results in lack of flexibility in small plants and excessive cost of wash-water system in large plants. Having too many units will increase the cost of both construction and operation. If the plant is a large one more operators will be required and in any case the cost of concrete, rate controllers, gauges, operating tables, wash-water troughs and valves will be unnecessarily large. Plants are occasionally seen in which an error has been made in selecting the number of units. A more common cause of unsatisfactory size of unit is that the ultimate size of

TABLE 1

Desirable number of filter units

PLANT CAPACITY, M.G.D.	NUMBER OF UNITS	PLANT CAPACITY, M.G.D.	NUMBER OF UNITS
0.31 to 0.86	2	16.6 to 23	12
0.86 to 1.68	3	23 to 31	14
1.68 to 2.8	4	31 to 44	16
2.8 to 4.2	5	44 to 66	20
4.2 to 6.7	6	66 to 93	24
6.7 to 11.1	8	93 to 123	28
11.1 to 16.6	10		

plant is much greater than the original installation. If the size of unit is small enough to give flexibility in the first installation, it may be too small for economy in the complete plant. In such cases some compromise is necessary. It may be wise to make the unit size in additions to the plant larger than that in the original installation.

It appears that the desirable number of units varies about as the square root of the capacity of the plant, except in plants of more than 100-m.g.d. capacity. The formula, $N = 2.7\sqrt{P}$, will indicate a suitable number of units in a given case. The value N is the desirable number of units and P in the total nominal capacity of the plant in million gallons per day. The number of units must be of course a whole number and in the larger plants, for convenience of layout, it should usually be a multiple of two or four. Table 1 is calculated from the formula and shows a number of units which will be generally satisfactory for a plant of any size less than 100 m.g.d.

In plants of over 100 m.g.d. capacity the desirable size of unit is determined by the economics of the wash-water system, rather than by any question of flexibility or number of operators. It is probable that no filter unit, unless the conditions are very peculiar, should be so large as to require a wash-water supply of more than 30,000 gallons per minute. Perhaps even this limit is too large for economy. How large the filter can be is thus a question of the washwater rate to be designed for. This should probably be between 30 and 42 inches of vertical rise per minute. If air wash or other means of agitation is to be used, or if the filter sand is unusually fine, a lower rate than 30 inches may be proper, but under ordinary conditions this should be minimum. A wash-water supply of 30,000 gallons per minute will provide for a filter unit having a sand area of 1600 square feet if the wash rate is 30 inches. If the rate of filtration is 125 m.g.d. per acre then the nominal capacity of one unit will be 4.60 m.g.d. For a 36-inch wash rate the maximum economical size of filter unit would be 1340 square feet and the nominal unit capacity would be 3.83 m.g.d. If a wash rate as high as 42 inches per minute must be provided for, then the maximum economical size of unit will be 1140 square feet and the unit capacity will be 3.28 m.g.d.

The objection to using a wash-water supply of more than 25,000 or 30,000 gallons per minute is that the cost of valves and piping increases rapidly and the piping becomes so cumbersome that the pipe gallery will have to be made larger than would otherwise be necessary. A larger wash-water tank may also be required and the capacity of drains or other means of removing wash water must be increased. All these conditions seem to fix the maximum economical size of filter unit as between 1200 and 1600 square feet, even for very large plants.

Rapid filters are usually designed to operate at a constant rate, whether they are clean or nearly ready for washing. Thus the hydraulic resistance or "loss-of-head" increases as the filter run progresses, being 1 or 2 feet at the start and from 4 to 14 feet at the end of the run. The available loss-of-head is an important element of the design, and the determination of the most desirable value requires careful study. In some cases, such as the insertion of a filter plant between an existing reservoir and pumping station, the choice is much restricted and the loss-of-head adopted may be much different than would otherwise be economical. Under ordinary conditions it is usually found that the maximum loss-of-head in the filters should be between 8 and 12 feet.

There is little variation in the depth of filter boxes unless the loss-of-head for which they are designed is unusually large. The internal construction of the filter establishes a certain minimum, but it is not usually the controlling factor. If the depth of filter box is made too small a partial vacuum will be produced in the gravel and the underdrain system near the end of each filter run. Under these conditions it is difficult to prevent leakage of air into the system and even if this does not occur air dissolved in the water is apt to come out of solution and accumulate in the lower part of the filter. This air may cause air-binding in the filter and various other operating difficulties, such as disturbances of gauges. Thus it is generally wise to make the depth of the filter box one or two feet greater than the maximum loss-of-head designed for, even though this depth is somewhat greater than would otherwise be necessary.

WASH WATER DISTRIBUTION SYSTEM

It is customary to give the name "underdrain system" to the arrangement of gravel, screens, strainers, piping or other devices that stand between the bottom of the filter sand and the main effluent pipe of the filter. This name is rather unfortunate as it places the emphasis on only one of the two functions of the system and that the least important. If the arrangements were only for the purpose of draining away the filtered water they could be much simpler and less expensive than is actually necessary. The conditions while the filter is being washed determine the construction. The name "wash-water distribution system" is too long for general use, but it describes better the purpose of the devices in question. The velocity of the water in the distribution system during washing is generally from 7 to 13 times as great as that during filtration. Thus if the pipe sizes, orifice openings and pores of the gravel are large enough to handle the wash water, they are much more than ample during filtration.

There is no other feature of filter design where practice is so diversified as is the case with filter-bottom arrangements. To make even brief mention of the various devices that have been adopted would take more space than is available. Many of the plans adopted may have been entirely suitable under the special conditions where they were used, but need hardly be considered for ordinary conditions. If the water to be filtered is very aggressive to iron and steel or if certain sizes of gravel cannot be obtained at reasonable cost in the locality, then special methods of construction may be advisable. For

most conditions, however, satisfactory results can be obtained with a perforated pipe system and graded gravel layer of conventional type.

Certain details require careful attention. The pipe sizes must be large enough so that the loss-of-head is not excessive at the washing rates provided for. High velocities also introduce another complication due to recovery of velocity head. This phenomenon could be prevented by the use of tapering pipes, but these are impractical. Using cylindrical pipes the velocity decreases and the pressure increases as portions of the water leave the pipe at each orifice. The effect of friction is to make the pressure decrease along the pipe in the direction of flow, but the recovery of velocity head usually more than offsets this, so that the pressure in the distribution system is greatest at the dead ends of the lateral pipes. The tendency of this is to make those portions of the bed where the pipe velocity is high receive less than their proper share of the wash water. The difficulty can be largely overcome by designing the pipes large enough.

It is the aim of the distribution system to produce a uniform upward velocity of wash water at all points in the bed. Under practical conditions, however, it is inevitable that there should be some variation in the amount of resistance offered to the water in different places in the bed. For the reasons above stated there will also be some variation in pressure in the different parts of the pipe system. The method usually adopted for overcoming both of these difficulties is to introduce a definite and rather large amount of resistance in the form of an orifice at the point where the water leaves the lateral pipe and enters the gravel layer. By making the drop in pressure here large enough the other variations in pressure become unimportant and the upward velocity of wash water is substantially uniform at all points over the area of the bed.

It has been recently shown that it is a very difficult thing, on a commercial basis, to drill in a steel pipe a row of holes having uniform hydraulic characteristics. Some of the difficulty is due to wear or variation in drills, causing slight but important differences in the diameters of the holes. An even more important cause of trouble may be the presence or absence of slight burrs at the inside ends of the holes. These would have considerable effects on the discharge. Neither of these reasons seem to explain the difficulty completely, but the fact remains that the holes do not discharge uniformly, even when they are drilled with considerable care. This, together with the danger of rusting in a plain hole through the pipe wall, make it

wise to use bronze or brass bushings in the holes unless some one of the common types of strainer is to be used. It is much easier to secure exact uniformity of dimension in bushings or strainers that are separately manufactured than it is in holes that are drilled in the pipe. It also seems wise, at least in the case of bushings, that they should project a short distance inside the interior wall of the pipe. This makes the entrance conditions more nearly uniform for all orifices and minimizes the disturbing effect of any burrs that may be present.

DEPTH AND GRADING OF GRAVEL

In comparing designs of different rapid sand filters there is some possibility of misunderstanding because of the fact that certain material which is called gravel by some designers is called coarse sand or torpedo sand by others. In concrete practice it is generally considered that the dividing point between sand and gravel is at the four-mesh sieve, represented by particles having an average diameter of about $\frac{3}{16}$-inch. Much finer material is sometimes called gravel in filter practice. In the following discussion all material larger than $\frac{1}{16}$-inch in size will be considered with the gravel, although it is realized that material from $\frac{1}{16}$- to $\frac{3}{16}$-inch would be more accurately described as torpedo sand.

In specifying filter gravel, as in many other things, it is decidedly a question of balancing desirable qualities against the cost of obtaining them. The ideal gravel, in quality of stone and exactness of grading, will often be so expensive that it is much better to make less rigid specifications. A perfectly satisfactory filter can be made with less than ideal gravel, but the gravel bed must be thicker than would otherwise be necessary. That arrangement should be selected that will be least expensive and most satisfactory in the long run.

Offhand it would appear that filter material should be of material that is decidedly insoluble. It is sometimes specified that at least 95 percent shall be insoluble when the material is crushed and digested in concentrated hydrochloric acid. For Detroit conditions, however, it has been shown definitely that the cost of meeting this requirement is entirely out of proportion to its importance. Using the best local glacial gravels about 50 percent of the material will dissolve in the acid, even if all weak and soft pieces are first removed. These gravels have been in successful use in water filters for at least ten years and there is no evidence whatever of any deterioration. The possi-

bility of trouble seems to be greater in the small sizes and it happens that very insoluble gravel can be brought in at moderate cost in sizes less than about $\frac{3}{8}$-inch. Thus in the construction of the new Springwells plant at Detroit local material was used for all gravel larger than $\frac{3}{8}$-inch and high-silica gravel from a distant point for all smaller sizes.

It was found practical to specify the grading of the gravel within closer limits than will often be the case. The gravel bed was built up of six layers, the nominal maximum size of the material in each layer being about twice the nominal minimum size, except in the case of the finest layer, where the limiting sizes were $\frac{3}{16}$- and $\frac{1}{16}$-inch. This amount of spread between the nominal sizes is not unusual, but it is often not specified how close the actual grading shall conform to the nominal limits. In order to secure gravel at a cost that is at all reasonable, it is necessary to permit a certain percent of the material to fall outside the nominal limits. In the Detroit specifications it was provided that 10 percent might be larger than the nominal maximum size and 10 percent might be finer than the nominal minimum. It is doubtful whether specifications should ever be more rigid than this. In some cases, especially for small plants, a considerably greater tolerance should be allowed, even though the resulting material is less satisfactory. Unless a screening plant is especially equipped to produce filter gravel it will be difficult and expensive to produce material having less than ten percent above and ten percent below the nominal limits.

Accurate sizing of the gravel within narrow limits results in better distribution of wash water and makes it possible to use a thinner bed of gravel than would otherwise be necessary. In order to provide a permanently stable gravel bed it is necessary that the finest particles of any layer should be smaller than the openings between the particles in the next layer below. The maximum size, used for the bottom layer, is determined by the fact that it must be large enough not to be disturbed by the rush of wash water from the pipe distribution system. Gravel from 2 to 3 inches in size is surely large enough for the purpose, even when high wash water rates are used. The size of gravel necessary in the finest or top layer is determined by the size of the coarsest particles in the filter sand. This is an important matter which should not be overlooked. The methods of commercial preparation of filter sands are such that they vary very much in size of coarse particles, even though the "effective" or 10 percent size is the same. Even when the uniformity coefficient also is identical it is possible for the

sands to differ considerably in the amount of coarse material. If at least two percent of the filter sand is coarser than 1.00 millimeter in size, then a gravel well graded between the limits of $\frac{1}{16}$- and $\frac{3}{16}$-inch in size is entirely satisfactory.

Having determined the sizes of the finest and coarsest layers of gravel, it is necessary to interpose several other layers, each sufficiently fine to hold up the material in the layer next above. Of the many possible arrangements, the following has been found to be entirely satisfactory where accurately graded gravel is obtainable.

GRAVEL NUMBER	THICKNESS OF LAYER	NOMINAL SIZE—INCHES SQUARE	
		Maximum	Minimum
	inches		
6	2	$\frac{3}{16}$	$\frac{1}{16}$
5	2	$\frac{3}{8}$	$\frac{3}{16}$
4	3	$\frac{5}{8}$	$\frac{3}{8}$
3	3	1	$\frac{5}{8}$
2	3	2 (round)	1
1	5	3 (round)	2 (round)

It will be noted in each case the nominal maximum size of each layer is the same as the nominal minimum size of the layer next below. The total thickness of the gravel bed is 18 inches. The lateral pipes of the wash water distribution system are embedded in the lower layers of the gravel, the bottom of the pipe being two inches above the floor of the filter. This brings the upper line of the bottom layer just above the center line of the lateral pipes.

FUNCTION OF SAND LAYER

It should be clearly understood that most of the sand in a rapid-sand filter has little or nothing to do with the filtering process. Its purpose is structural, rather than having to do with the removal of turbidity or bacteria from the water. As has been said of the lower two-thirds of the water in a standpipe, its only use is to hold up the other one-third. Possibly this statement is a little too general. Some competent observers believe that under certain peculiar conditions all of the sand in a filter is effective in removing and storing up a fragile floc. Certainly it is true for most conditions that practically all the filtering is done in the first few top inches of the sand. If a filter has been operated in such a way as to keep it in good condition,

an examination of the sand just before washing will usually show little or no clogging at depths greater than two inches. It is conservative to say that the actual filtering medium in most filters is not over six inches thick.

After a new filter has been thoroughly washed for a sufficient length of time the sand is found to be hydraulically graded. That is all the coarsest particles are at the bottom, and the grain size increases regularly with the distance down from the sand surface. Tests have shown the actual grading to be very close to what would theoretically be expected. Thus the top six inches, which may be considered as the true filtering layer, includes all the fine material. The remainder of the sand is by no means useless however. It is necessary as an intermediate support between the fine sand at six-inch depth and the finest layer of gravel. Otherwise during washing the fine sand would penetrate into the gravel. Nevertheless the thickness of this part of the sand bed is often much greater than necessary. With ideal sand sizing a total sand thickness of twelve inches will give entirely satisfactory results under most conditions, and it is quite possible that even thinner beds would be satisfactory. Many designers feel that the additional thickness provides a desirable factor of safety. The cost of providing 24 to 30 inches of sand is usually not serious as compared with the total cost of the filter and additional thickness may be even less expensive than the very accurate sizing that is necessary if minimum sand thickness is to be used. It should be remembered, however, that unnecessarily thick sand layers will be troublesome and expensive if they ever have to be entirely removed or worked over for cleaning.

Considering now the finer portion of the sand, it is all but generally admitted that the present common method of describing or specifying filter sand by "effective size" and uniformity coefficient is decidedly unsatisfactory. When a 24-inch bed of sand is hydraulically graded, the effective or 10 percent size is that which will be found at a depth of 2.4 inches from the surface. Since little or none of the clogging material ever reaches this depth below the surface, the size of sand at that point is not particularly important. What is of great importance is the size in the top inch, and particularly in the top quarter or eighth of an inch. It is the size of the sand on the top of the filter which decides how fine material it will remove from the water and how soon the filter will clog. For Detroit conditions it was concluded that any material less than 0.30 millimeters in size was undesirable.

Some may feel that top sand should be finer than this, but in any case the top size should receive serious consideration.

The size of the top filter sand is quite easily adjusted, particularly if it is too small. By scraping off a thin layer, after new sand has been thoroughly washed, the minimum size can be increased to any desired extent. Similarly the top size can be decreased by adding a few inches of sand of proper size characteristics.

HYDRAULICS OF FILTER SAND

To decide intelligently what the size characteristics should be of a filter sand for a given purpose, the filter designer should have certain information which has never been available. For practical filter operation the sand should be such that the filter will run a reasonable length of time without washing, insofar as this is consistent with proper purification. If the filter runs expected under average raw water conditions are from 24 to 36 hours, and if the difference between the initial and final losses of head is 8 feet, this means that the loss of head, when operating at the design rate, should increase at a rate of from 2.67 to 4.00 inches per hour. This rate of increase of loss of head in a filter operating under standard conditions is a factor of prime importance, and is sure to receive more attention in the future than it has in the past. For a short name it might be called the "clogging rate."

It is rather surprising to consider that there is available to engineers practically no information as to what effect size of sand has on clogging rate. It is reasonably certain that making the surface sand in a filter finer will increase the rate of clogging, but there are no numerical data as to how the clogging rate changes as the sand size decreases. It is not at all certain that changing the sand size in the lower levels of a bed had any effect at all on the clogging rate. To what depth the sand size affects the rate of clogging is not known. Probably the formula expressing the effect of sand size is different at the surface than it is at a depth of one or two inches, but all such formulas are unknown.

The effect on purification of sand size at different points in the depth of the filter is of even greater importance than the effect on clogging rate. It seems, however, to be considerably more difficult to investigate experimentally, so it is likely that the laws connecting sand size and clogging rate will be first studied.

Until recently even the laws governing the flow of clean water

through rapid-sand filters were very imperfectly understood. The investigations of Hulbert and Feben have largely settled that question. (Journal, January, 1930.) If an accurate sieve analysis has been made of a certain sand, it is now possible to calculate with considerable certainty what the initial loss of head will be when a filter containing a known depth of that sand is operated at a known rate. Anyone applying the formula may be surprised to learn how great is the effect, in causing resistance to flow, of that part of the sand finer than the 10 percent or "effective" size. If the average size of grain in the top half-inch of the sand of a filter is reduced by half, the resistance of that lamina is multiplied by four. This shows the great importance of having the top sand of a filter no finer than is really necessary. It is still a matter of conjecture, of course, whether the effect of fine sand on clogging rate is similar to that on initial loss of head with clean water.

SPECIFYING FILTER SAND

Even if the engineer had information enough to determine exactly what was desirable in the way of filter sand, the sad fact would remain that it probably would be impractical to secure such material. By good luck the sand desired might happen to be very close to a product actually offered by some filter sand manufacturer. If this were not true the producer might find it possible to change his product to meet the requirements. Much modification, however, might increase the cost of the sand all out of proportion to the advantage to be expected from the change. Therefore specifications should be prepared only after careful consideration of the available sources of supply.

The common way of specifying filter sand has the effect of fixing two points on the sand analysis curve. These are the "effective size," the size such that ten percent of the material by weight is finer, and the similar 60-percent size. The specifications should fix these two points within certain limits, but they alone are not sufficient to determine the character of the sand. Consideration should also be given to other points on the analysis curve, possibly the 30, 90 and 98 percent points. Where the available sand sources permit, these points also should be fixed within the limits by the specifications.

WASH WATER TROUGHS

The design and spacing of wash-water troughs is discussed in standard text books. There is one point, however, that does not

appear to be covered and which may be very important, particularly in large filter units. This is that the bottom of the wash-water troughs should be high enough so that when the sand is expanded during washing it will be a few inches below the bottom of the troughs. It is obvious that the upward velocity of the wash water is considerably higher between the troughs than it is immediately below them. Thus if the top surface of the expanded sand comes above the bottoms of the troughs, there may be considerable loss of fine sand that would not otherwise occur. The increased velocity, particularly close to the sides of the troughs, is sufficient to carry the fine material over the lips of the troughs and away to the drains. The so-called "freeboard" of a filter, that is the distance from the surface of the sand at rest to the lip of the wash-water trough, does not seem to be of as much importance as was formerly supposed. The relation between the top of the expanded sand and the bottom of the troughs seems to be the controlling factor.

FILTER EQUIPMENT

To describe in detail all the items of filter equipment would take much more space than is available. Mention will be made, however, of a few points that are not commonly given as much attention as they deserve. The first is the matter of loss of head in filter effluent piping, particularly in rate controllers. In most plants, provided they are otherwise well-designed, any unnecessary loss of head here represents a waste of power. By decreasing the size of the controller body the manufacturer will produce a less expensive piece of equipment, but the resulting loss of head may be decidedly objectionable. The engineer should specify in some way the allowable loss of head in rate controllers, setting the figure at such a point that the saving in power and pumping costs will more than offset the additional cost of the rate controllers.

Gate valves are important accessories of filters. It is sometimes forgotten that filter valves are subjected to a tremendous amount of use as compared with some other kinds of valves. Whereas a valve in a water distribution system may be operated only once a year, the filter valves may be opened and closed three or four hundred times in a year. The resulting wear is a serious matter, particularly in large valves. Better construction than that usually specified may prove more economical in the long run. Many valves that are called "brass mounted" still have certain moving-contact surfaces that are of

ordinary machined cast iron. These should be avoided. The more important brass mountings, such as the seat and disc rings, should be heavy and well secured.

All large valves that are frequently used should be power-operated, usually by hydraulic cylinders. The cylinders should of course be bronze-lined to prevent corrosion. This is commonly done on the sides of the cylinders, but not usually on the ends. Rust accumulating on the heads of the cylinders may come loose and cause scoring of the interior. Lining the cylinder heads also will probably eventually save all it costs.

Every precaution should be taken to keep rust and dirt out of the valve cylinders. A strainer is to be recommended on the discharge of the pump supplying the hydraulic pressure water. Cast-iron pipe is fairly satisfactory for conveying the water to the cylinders, but small connecting pipes and fittings should be of brass or copper rather than of steel or iron.

THE CARE OF FILTER UNITS

Before going into the subject of the care of filter units, it must be thoroughly understood that the water purification plant operator is preparing for the consumer a product, which in most cases is delivered immediately, and which cannot be held for confirmation of its quality. To use a rather trite expression, eternal vigilance is required to safeguard the quality of this finished water.

The care of filter units may be divided into three principal parts, which, of course, may be further divided. These basic divisions consist of inspection and calibration to determine any defects and the remedies for the same. The three main divisions are (1) inspection and care of the sand and gravel; (2) inspection, calibration and maintenance of the appurtenances; (3) bacteriological and physical testing of the effluent. The appurtenances of filter units consist of the rate controllers, rate and loss-of-head gauges, operating tables, hydraulic valves and the under drain system.

Ordinary inspection of the filter sand, which should be made at regular intervals, is best accomplished by lowering the water to within a few inches of the surface of the sand. The appearance of cracks in a sand bed which is under water indicates that the sand grains have become coated by some compressible material which has caused shrinkage. Inasmuch as clean beds show slight shrinkage during the filtering period, the size of these cracks should be recorded in order

that comparisons may be made at later inspections. Most cracks appear at the side walls and as the rate of flow of water is then increased at these points, the deposition of foreign matter is increased forming a dense mass which is known as a side wall accumulation. If these side wall accumulations are not prevented or remedied they in time become large masses which extend for some distance in and above the sand. Occasionally similar accumulations occur in other parts of the bed causing dead areas.

Mounding and mud-balls are best detected by draining the bed. Mounding, of course, is indicated by raised areas of the sand which may extend over a portion of the bed. The presence of mud-balls is best determined by digging a large hole in the sand, all the way to the top layer of gravel, and exposing a cross section of sand wherein the size and frequency of the mud-balls may be noted.

Experience has shown that these sand troubles, with the exception of mounding, may be prevented by preparing the water properly for filtration and by correct washing procedure. It is appreciated that in many plants it is not always possible to prepare a satisfactory applied water and that in some plants it is almost impossible, due to st ructural layout, to obtain a satisfactory wash.

At this time it might be well to describe a satisfactory wash. In the first place, proper distribution of the wash water over the entire surface is necessary and in the second place, a sufficient rate of wash must be obtainable to thoroughly cleanse the sand. It has been found that the rate of wash is not the proper criterion of proper sand washing, but rather the percent of expansion of the filter sand. It might be thought that depending on the rate of wash would give satisfactory results, but this is not so. If two filters differ in sand size, the same rate of wash will give entirely different degrees of sand agitation. In the same filter considerably different degrees of sand expansion will be obtained when the water temperature varies although the rise is the same, but the expansion of the sand seems to be a direct measure of the degree of agitation which is the really significant thing.

Recent studies in several plants have shown that to maintain the sand in good condition an expansion of at least 50 percent should be maintained. A 50 percent expansion means that a sand bed having a depth of 24 inches when at rest will have this depth increased to 36 inches when being washed. (Hulbert and Herring, Journal, November, 1929.) An increase of temperature from 40° to 80°F requires about a 50 percent increase in wash water to maintain the same sand

expansion. The lack of proper appreciation of this fact has been the cause of some failures to keep the sand in proper condition.

It was at one time generally believed to be desirable to stop the washing of a rapid sand filter before the wash water was entirely clear. It was thought that washing too clean would cause less satisfactory filtration results but this is not so. The washing process should be continued until the sand is plainly visible all over the bed.

If, as stated before, a satisfactory wash can not be obtained, there are several means by which the filter unit can be kept in proper condition. Side-wall accumulations may be removed by digging or they may be broken up by a long handled rake (using an up and down motion) while the sand is being washed. Mud-balls may be eliminated and the coating on the sand grains reduced by draining the bed and subjecting the upper 12 inches of the sand to the action of a high pressure hose stream. This application of high pressure water should be carefully and thoroughly made.

It might be well to point out that, in case a plant operator should decide to change from a low rate of wash to a high wash, that the sand should be thoroughly cleaned before so doing, as coated sand is much lighter than clean sand and a loss of sand might result. Coated sand, due to its lower specific gravity, is more easily floated than clean sand and a loss of sand might result. A small percentage of coating material by weight represents a larger proportion by volume. If an application of high pressure hose wash does not satisfactorily remove enough coating, the bed should be subjected to a sodium carbonate treatment. (Wallace, Hulbert and Feben, Journal, June, 1931.) It is very easy to calculate the percentage of coating by determining the specific gravity of the sand.

Mounding indicates a disarrangement of the gravel layers, caused either by a clogged strainer or by discharge of air during washing. Sufficient gravel should be removed, the clogged orifice repaired and the gravel screened and relaid in such a manner that the layers will exactly coincide with the original strata.

Taking up the subject of care of appurtenances, it must be remembered that rate controllers and rate and loss-of-head gauges get out of adjustment and are subject to error, and that 4-way valves and hydraulic cylinders get dirty or corrode. The same systematic and careful attention which is given to the filter sand and gravel, must be extended to the mechanical equipment.

Filter rate and loss-of-head gauges should be checked at regular intervals and necessary adjustments made. Filter rates may be

easily and accurately checked by means of a drop apparatus devised in the Detroit plant. A complete description will be found in Water Works Engineering, August 12, 1931, page 1139. This apparatus can also be used to measure wash water rise. The calibration of the loss-of-head gauges is accomplished very easily by means of a manometer. In doing this it must be remembered that a mechanical lag in the instrument will cause the gauge error to vary with different readings. If a lag exists the gauge should be adjusted so that the minimum error occurs in the middle of its range, rather than at the zero point.

Regular study of filter charts will often indicate some irregularity in the rate controller operation in time to prevent serious operating difficulties. Excessive variations in rate and loss-of-head curves indicate trouble in the equipment or in the plant processes.

The opening and closing time of hydraulic valves should be observed and recorded at stated intervals in order that any sluggishness of operation may be detected, before serious trouble occurs. Sluggish valve operation indicates the need of replacing gland packing, cleaning of hydraulic cylinder and perhaps the replacement of cup leathers. Considerable trouble in valve operation may be avoided by the regular cleaning of strainers in the pressure lines.

Considering the third division of filter care, the testing of filter effluents, it might appear at first that this is only of importance in determining the quality, but such is not the case.

Comparisons made over a long period of time have definitely established the fact that the effluent from a filter containing clean sand is superior to the effluent from a filter having side wall accumulations or in which the sand is coated. The 20° count on agar is more valuable than the 37° count or the B. coli index in most plants. Due to the greater difference between raw and filtered water counts at 20°, changes in conditions are more apparent and any irregularity in operating conditions may be quickly perceived.

A turbidimeter which detects minute quantities of turbidity should be used regularly, as imperfect filtration is shown which may be due to faulty filters rather than to improperly prepared raw water.

In case the combined effluent from the filtration plant is not entirely satisfactory, samples for bacterial and physical tests should be taken from individual filters as the difficulty may arise from the condition of one or more filters. It is excellent practice to make tests on individual filter effluents occasionally.

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RADIUM POISONING IN WATER

By Leonard B. Loeb

(Professor of Physics, University of California, Berkeley, Calif.)

The problem indicated by the title of this article is of import to members of the American Water Works Association, not because radium poisoning is an element of danger in the problem of water supply but because of the fact that the radioactive properties in water have been extensively advertised as beneficial with dire results in some cases. It is therefore essential that the public be informed on the facts in order to counteract the effects of the dangerous advertising. For the sake of the emphasis the conclusions arrived at in this study may properly be summarized at the outset. There is no definite evidence to show that radium taken internally in water has any beneficial effects on the human system. If taken in exceedingly minute quantities no evidence of its effects are on medical record, and the water might be free from radium as far as the results are concerned. If radium is taken internally in amounts sufficient to produce any effect (and these amounts are amazingly small), it constitutes one of the most insidious, subtle and deadly poisons known to mankind. Accordingly anyone who knowingly sells water containing radium, radon or thorium preparations, whether through ignorance of the facts or otherwise, is guilty of fraud or homicide.

THE NATURE OF RADIOACTIVITY AND RADIUM (1)

All matter known to us is composed of some 92 elements which can be arranged sequentially in a table known as the Periodic Table of the Elements. The table begins with the element hydrogen as 1 and terminates with uranium as 92. Between lead, which is number 82, and the end of the table at element 92, there are ten places occupied by the heaviest and most complex elements known. Owing to the fact that the chemical behavior is determined by the atomic number (the number of the element in this table), it happens that several elements of different atomic weights can have the same number and thus be chemically identical with each other though differing

in mass. There are therefore 40 elements of different mass in this part of the table, and because of the complexity of their inner structures (the nuclei), these elements are exceedingly unstable; that is, their nuclei undergo spontaneous disruptions of a cataclysmic sort, transforming the element disrupted and liberating enormous amounts of energy relative to other changes known to us. These elements are divided into three disintegration series, the uranium-radium series, the thorium, and the actinium series. The process of disruption consists in the emission from the nucleus either of an alpha (α) ray or of a beta (β) ray. The α ray is a doubly charged atom of the inert gas helium moving with a velocity ranging roughly from three thousand million centimeters per second to two hundred million centimeters per second.[1] The β ray is an electron, a negatively electrically charged unit of matter $\frac{1}{1839}$ the mass of the atom of hydrogen and having velocities ranging from 0.99 the velocity of light (3×10^{10} cm./sec.) down to 10^7 cm./sec. As these particles leave the nuclei of the atoms they alter its nuclear charge, through the deduction of their proper charge, and the α particle loss reduces the mass of the nucleus by 4 atomic weight units while the β particle reduces the mass of the nucleus which it leaves by $\frac{1}{1839}$ of an atomic weight unit. Each transformation is accompanied *either* by an α ray *or* a β ray emission, never by both. Some α ray and most, but not all, β ray emissions are accompanied by the emission of gamma (γ) rays. These are x-rays of very great penetrating power such that the more penetrating ones can go through a centimeter of lead without much attenuation. While such rays have not as yet been produced artificially in the laboratory, the time is not far dis-

[1] It is essential in what follows to express the enormously great and the exceedingly small quantities discussed in the powers of ten notation. On this notation a superscript 3 after a ten means ten multiplied by itself three times and represents 1 with three ciphers following. A ten with a superscript -5 means the number 1 divided by ten multiplied by itself five times, or 1 divided by ten to the fifth power, that is 100,000. Thus one can write: $10^3 = 1{,}000$, $10^{-3} = \frac{1}{1{,}000}$; $10^6 = 1{,}000{,}000$, $10^{-6} = \frac{1}{1{,}000{,}000}$ = one one millionth; $10^9 = 1{,}000{,}000{,}000$, $10^{-9} = \frac{1}{1{,}000{,}000{,}000}$ = one one billionth; $10^{12} = 1{,}000{,}000{,}000{,}000$, $10^{-12} = \frac{1}{1{,}000{,}000{,}000{,}000}$ = one one thousand billionth.

tant when they will be. In the Radiation Laboratory of the University of California positively charged hydrogen atoms of three million volts equivalent energy and x-rays of one million volts equivalent energy have been produced to date (9). α rays have on the order of six million volts energy and β and γ rays of the order of two million volts. α rays penetrate 7 cm. of air and some 0.001 cm. of water or human tissues. β rays penetrate several times as much matter, while γ rays traverse the human body with negligible loss in intensity. The α rays in their short path in matter disrupt the external portions of some 100,000 molecules by removing electrons, i.e. they produce on the order of 10,000 ions per cm. of path in air. β rays produce a smaller density between 1600 and 100 ions per cm. in air. γ rays, as do x-rays, ionize by liberating fast electrons from an occasional atom. These fast electrons are identical in their properties with β rays. Hence a human body radiated with x-rays or γ rays receives mild ionization over a large volume, while a tissue surface subjected to α or β rays in contact with it is subjected to a withering bombardment and subsequent destruction in a very thin layer.

The essential effect of this ionization is to alter the structure of the molecules ionized by making fairly stable molecular groupings temporarily chemically active. This activation and the subsequent reactions are closely similar to those produced by ultraviolet light. In general the differences are quantitative rather than qualitative, though in some cases ultraviolet light acts specifically while this is not true of x-rays or radioactive rays. While chemical reactions produced by α ray bombardment have been studied by several workers (10), practically nothing is known of the detailed reactions, and certainly nothing is known of the reactions produced by these rays on such complex structures as living tissues. Unquestionably many and very diverse substances are formed, some of which may be beneficial and others probably very poisonous to the nicely balanced human body. The effect would be much like going blindfolded into a drugstore, picking at random small and varied samples from a thousand bottles, and injecting a sample of the resultant mixture into a man's muscle tissue.

The 40 different elements undergo their transformations according to a law which says that if at a given instant there are n_o atoms of a substance the number n at a time t expressed in years, days, hours, minutes or seconds is $n = n_o e^{-\lambda t}$ where e is the base of the natural

system of logarithms, 2.7183 and λ is a constant related to the half life period T of the element by the equation $T = \frac{0.693}{\lambda}$. T represents the time for a given quantity of substance to transform to half its initial value. This time varies through unbelievable limits varying from 10^{10} *years* for thorium to 10^{-9} *seconds* for *ThC* (11). The values of T for some substances are of importance to the present problem in that they tell how long the radioactive properties persist. They are as follows:

Radium	1590	years
Radon	3.83	days
Ra D	22	years
Mesothorium I	6.7	years
Thoron	5.45	seconds

One word more might be said about the chemistry of these elements. Radium is a member of the second group in the periodic table and its chemical behavior is closely analogous to that of barium and calcium. Hence it should be found in the body in places where calcium is stored. Radon, thoron and actinon are gaseous substances belonging to the *0* group in the periodic table along with neon, argon and helium. These gases, the radioactive emanations, are thus inert chemically and somewhat, but not very, soluble in water. They are distributed between blood and air in the ratio 30 to 40 percent in the blood and 70 to 60 percent in the air when in equilibrium at about body temperature. Mesothorium I is also analogous to radium in its chemical behavior, while radium D is closely related to lead.

THE NATURAL DISTRIBUTION OF RADIUM AND RADON IN THE EARTH'S CRUST (1D)

The origin of the radioactive elements is unknown. They may have been generated under the conditions existing in the interiors of stars such as the sun and left in the earth as it broke off from the sun mass. They may also be generated and stable under the conditions of temperature and pressure existing in the interior of the earth becoming unstable only as they reach the cooler exterior of the earth's crust. Whatever the origin, uranium, thorium and actinium, and consequently their decay products, radium and mesothorium, are widely distributed over the earth's crust in minute

amounts. In mineral deposits uranium and thorium may be segregated in large concentrations and these deposits furnish the sources for the extraction of radium, a very costly chemical procedure. In any case radioactivity is widely distributed in the earth's crust so that in minute traces the presence is continually manifest. The presence of radioactive substances in the earth's crust is shown in the actual presence of minute amounts of radium in ordinary rocks, which the beautiful new methods of Evans (2) and his collaborators are now making available to accurate quantitative assay. The presence is also indicated in the emanation content of the atmosphere and in waters of the springs and oceans. Another manifestation of the presence is seen in the emission of relatively large amounts of helium gas in the natural gas from oil wells, which is the present source of helium for our lighter than air craft such as the Macon. This helium comes from the α particles emitted by the traces of radioactive substance in the oil sands which have been accumulating for millions of years and escaping into the gas pockets above the oil under ground. Most dense rocks contain small traces of helium also, and Paneth (3) has devised methods for making the assay.

Before proceeding to discuss the quantities of these substances in various sources, a brief mention might be made of the units (4) used in order that those interested may be able to understand the data given in various reference works. The quantity of radium is expressed as grams, milligrams (mg. = 10^{-3} grams), micrograms (μg = 10^{-6} grams), millimicrograms (mμg = 10^{-9} grams), and micro-micrograms ($\mu\mu$g = 10^{-12} grams) of radium element. The concentration of radium is expressed in fractions of a gram of radium element per gram of rock or water. The quantities of radon gas are expressed in terms of curies, or fractions thereof (millicuries, microcuries, milli-microcuries, and micro-microcuries). A curie of radon is the quantity of radon in equilibrium with a gram of radium element. Essentially it is the amount of radon present in a gram of radium that has stood for one or two months in a closed vessel. In addition one reads of a Mache unit. This is a unit measured in terms of the ionization current produced by the α and β particles from the radon in a gas. It is a quantity which will contribute a saturation ionization current of 10^{-3} electrostatic units or 3.33×10^{-13} amperes. One Mache unit = 3.64×10^{-10} curie. Finally, concentrations of radon are expressed in Emans, in which an Eman = 10^{-10} curie of radon per liter.

It is now possible to list the amounts of radioactive materials usually found in various sources on the earth's surface. The figures are chosen to give an idea of the amounts present taken from a large mass of data. Local conditions may cause material deviations from these figures but they are representative of what is to be expected.

a. Radium emanations (principally radon) in the atmosphere (5)

1. Over land from 10 to 300 $\times 10^{-15}$ curies per liter.

2. Over the oceans 0.4–2.6 $\times 10^{-15}$ curies per liter (note the liter is roughly a quart). This difference is due to the fact that the radon issues largely from the earth where the radium concentrations are much greater than in the ocean as seen below.

b. Radium and radon in water

1. Radium content in the oceans (6).

a. Atlantic Ocean 1 to 2.5 $\times 10^{-12}$ grams per liter.

b. Gulf Stream 14 $\times 10^{-12}$ grams per liter.

c. Pacific Ocean undetectable.

2. Radium content of springs (7).

a. Saratoga (U. S.) 0.1 to 1 $\times 10^{-10}$ grams per liter.

b. Bath (England) 1.4 $\times 10^{-10}$ grams per liter.

c. Karlsbad (Germany) "Sprudel" 1 $\times 10^{-10}$ grams per liter.

3. Radon content of springs (7).

a. Hot Springs, Arkansas (U. S.) 90 $\times 10^{-10}$ curies per liter.

b. Karlsbad (Germany) "Muhlbrunnen" 115 $\times 10^{-10}$ curies per liter. Karlsbad (Germany) "Sprudel" 0.4 $\times 10^{-10}$ curies per liter.

c. Baden Baden (Austria) 290 to 450 $\times 10^{-10}$ curies per liter.

d. St. Joachimsthal (Alps) mine waters 7500 $\times 10^{-10}$ curies per liter.

e. Brambach (Central Europe) 6500 to 7500 $\times 10^{-10}$ curies per liter.

It is to be noted that the waters contain much more radon than radium. This is due to the fact that they wash over large amounts of insoluble radium containing rocks and carry off the emanation.

c. Radium content of rocks (8)

1. Granite rocks have in the order of 10^{-12} grams of radium per gram of rock, and this figure is in general representative of the radium content of ordinary rocks which do not represent mineral deposits.

2. Radium containing ores from mineral deposits have amounts of

radium in proportion to the uranium present, which proportion depends on the nature of the rocks and their age. In general the content is of the order of 10^{-7} grams of radium per gram of rock, or less. In many of the radium activators for water sold commercially such ores are used in view of the saving in using untreated ores instead of extracted radium which is very expensive. Practically the whole cost of radium lies in the expensive and tedious process of separation and crystalization. It retails at about $70,000 a gram.

BIOLOGICAL ACTION OF RADIOACTIVE PRODUCTS

As indicated earlier, the whole biological activity of radioactive preparations can essentially be led back to the ionization produced by the α, β, and γ rays emitted. These produce chemical changes of an unknown sort in the complex organic compounds in the tissues. Their effect depends on the number of ions produced in unit mass of tissue, and apart from secondary effects due to the time element in elimination on prolonged exposure, this means that the effect is roughly proportional to the product of intensity of ionization produced by the radiation and the time of exposure. As in all biological reactions, the reaction of individual cells and individual subjects is open to an extremely wide range of variation. Just as with drugs amounts capable of killing one individual can be increased many fold before affecting others. This is one of the great difficulties encountered in the treatment of individual cases by x-rays or radium on the part of legitimate medical practitioners. It requires the greatest caution and experience to avoid most serious consequences.

In regard to the action of individual cells to these rays, some progress has been made as a result of numerous researches (11, 12). Prolonged intense radiation ends in the death of all cells (15, 16). In some cases it has been possible to determine the effective volume of cell which must be struck by one α ray or one β ray (primary β ray from radium or secondary β ray from x-rays or γ rays) to cause the death of the cell (13, 14). Certain cells are much more susceptible than others (15). This is especially true of what may be called young cells, i.e. cells that are rapidly proliferating or highly active. Among these cells are the cancer cells, which appear to be normal body cells that have suddenly taken on a greater capacity for growth and multiplication, thus crowding out normal cells and so invading the body as to cause death by impairing normal bodily functions. Other cells that are easily affected are the cells of the male and female

reproductive organs which give rise to the ova and spermatozoa, the thyroid gland, the lymphatic glands, the leucocytes, and probably the cells that produce the red blood corpuscles.

Smaller amounts of radiation appear to stimulate the activities of certain cells. Very definite changes in the blood picture follow mild treatment of human individuals with radiations, such, for instance, as a sudden decline of the lymphocyte count followed by an abnormal rise. How this is accomplished is not known. Certain claims are made that mild doses produce general beneficial effects (17). The curative action of mineral springs has been attributed to this cause. Also an increased growth in plants subjected to mild doses has been claimed. The many factors involved in the treatment of mineral waters and the psychological factors involved in such treatments must *make one doubtful of this evidence as it comes from inadequately controlled experiments.* The same may be said of the experiments on increased growth which in general have not been adequately controlled. The *very* carefully controlled experiments of the geneticists (11, 12) do not indicate such beneficial effects. What effects have been observed have been stunting of growth, change of leaf and flowering habits, all of which are in a sense a degeneration. Thus great care must be used in accepting the idea of the beneficial effect of small doses. It has been observed in the fruit-fly, drosophila melanogaster, that sub-lethal doses produce mutations (11, 12, 18, 19), i.e., changes in the germ cells leading to new species, although most mutations of this type as with natural mutations appear to be of the lethal type. In the case of the germ cells of tobacco plants and cereals exposed to x-rays, Goodspeed (11) and Stadler (19) have shown that a very complex set of mutants are formed, some of which are viable and stable. These mutants so far are all of an abortive and inferior type, many being sterile. In any case, the mutants so far found have not been improvements on the species. It is probable that the stimulating effect of radiations of this sort in the growth of more complex organisms, and especially of animals, is in part ascribable to the creation of very active mutants which grow at the expense of normal cells in the environment. Hence it is not surprising that x-ray and radium burns frequently lead to the development of cancer. All that is needed is that perhaps one of the cells in a fortuitously happy environment under radiation undergo a mutation to an active or cancerous type which may then ultimately lead to a malignant growth.

It can be generally stated that the result of radiation may not immediately be noticeable or felt by the individual as is the case with ordinary burns. There is generally lag period during which no effect is noticed. Thus radium and x-ray burns may follow as much as a month to six weeks after exposure. In extensive radiation of the human body there may be a considerable reaction, or shock, following some hours after the exposure, probably due to the production of toxic substances by the rays following radiation. On the elimination of these substances, this effect gives way to a latent period during which the metamorphosed cells begin to develop when further effects, such as burns, resorption of glands, etc., occur. The development of the most serious phases of the action of radium, such as cancers, may be delayed as much as years, in which time the metamorphosed cells multiply to masses which are capable of being diagnosed.

PROPER MEDICAL RADIUM OR X-RAY TREATMENT (20)

In cases where the treatment with radiations from a medical point of view is indicated, these must be resorted to with great care. In such cases it is the purpose to radiate a region of the body in such a fashion that the affected region (cancer or thyroid gland) receives enough radiation to kill the undesirable cells and to leave the normal cells in that and adjoining regions unaffected. This requires very accurate dosing, with controlled experimental procedure, to avoid accidents due to individual variations. The radiation treatment causing a local ionization must be so controlled that its quantity is definitely limited and known. Accordingly all such treatments utilize the preparations such as radium or mesothorium I of accurately known strength in *removable containers*, placques, hollow needles, glass-walled emanation tubes, etc. In general where possible, cross radiation by x-rays or γ rays is used. *In no case is the radioactive preparation distributed through the tissues* or brought in direct contact with them. The α and β rays are never used, with the possible exception of the external skin, because of their limited penetration and locally highly destructive nature in consequence of the intense local ionization produced by them. Hence it is seen how carefully in how restricted a fashion the licensed medical practitioner applies these useful but dangerous substances. Contrast this procedure to the application of the vendors of radioactive water.

INGESTION OF RADIUM BY THE HUMAN BODY (21, 22)

Radioactive preparations have been introduced into the human body in the following ways:

1. Through the unconscious ingestion of radium or thorium salts in the pursuit of the profession of painting the luminous figures on watch dials.

2. Through the activity of radioactive nostrum vendors who sell preparations in which radium, mesothorium I or radon is taken into the body by mouth in water or is injected into the blood stream.

3. Through the lungs, in the cases of certain operators in radium plants, who inhale the emanation and radioactively contaminated dust of the rooms of the plant.

Of the various methods of ingestion the first method has unfortunately given most data on the poisoning and its results (23). This is due to the excessively large doses taken. It is estimated that before the dangers of tipping the brushes in the lips of the dial painters became known, some 800 persons were exposed to the poisoning, among whom 30 deaths to date are on actual record, and doubtless a much larger number have occurred with inadequate diagnoses, death being due to secondary causes such as cancer, anemia, etc. In this occupation the dials of watches have figures painted on them made of phosphorescent zinc sulfide containing a small amount of radium or mesothorium I carried in a suitable enamel and solvent vehicle. After making the letters, the mistakes are corrected by a fine point-like brush whose tip can be made sharper by moistening with the lips. On this basis it is possible for an individual operator to have taken some 4000×10^{-6} grams of radium element a month. When it is realized that 2×10^{-6} grams in the human body can prove fatal, it is seen that even with the best elimination the risk is great. This source of poisoning was discovered by chance by an oral surgeon (24) who was surprised at the necrosis of the jawbone of a woman patient whom he was treating. He had the acuity to suspect some obscure poisoning, and inquiry revealed the source as radium. Promptly other cases were discovered and an end was put to this industrial hazard.

Of the cases on record due to use of radioactive waters there have been distinctly less. Those on record are due to persons who have either had injections of radium salts dissolved in water or who have taken appreciable quantities of these salts in drinking water (25).

The few horrible examples of this mode of poisoning on record are probably distinctly less than the real number of victims, owing to the unusual origin of the illness (usually not suspected by practitioners) and the fact that death is immediately caused by conditions which are all too frequent without the use of radium, so that radium is not looked for as the cause. Finally, the vast majority of users of radioactive preparations use water activated by sources which contain practically no soluble radium salts but do contain varied quantities of radon. These sources fortunately have been fraudulently weak in many cases, and as will be seen, radon alone is usually rapidly eliminated from the body.

The third method of ingestion, that through the lungs, has presumably not proven fatal for the same reason, that radon is quickly eliminated and only small quantities are taken in. There are, however, records of continued ill health and anemia on the part of such workers. Furthermore, these operators are usually in medical or technical plants where the menace is recognized and operators are watched.

The rate of ingestion by these various methods can be summarized as follows:

Tippers may take in 4000×10^{-6} grams of radium a month.

Drinkers of emanated water under average conditions may take in perhaps 2.1×10^{-9} curie per liter of water, about 3×10^{-7} curie of radon a month, and 2.0×10^{-7} grams of radium a month.

The amount of radon inhaled depends on conditions and can not be estimated.

RADIUM AND RADON ELIMINATION IN THE BODY (26)

One may first consider the elimination of radon. The radon which is not retained in solution in the fluids of the body and thus eliminated in the urine and feces, is absorbed by the tissues and goes to the blood stream. By the blood it is carried to the lungs. Since in equilibrium about 58 to 69 percent by volume remains in the air, the blood is quickly freed of radon. Moreover, radon is an inert gas which does not combine with substances in the body so that it is eliminated with some speed. It is estimated that most of the radon taken in by mouth is eliminated in 3 to 4 hours. During this period between 1 and 2 percent of the radon in the system decays to radium A and its products, and remains in the body as radium D which has a

half-life of 22 years and is chemically similar to lead. Much of this material may subsequently be eliminated through the excretions.

Not so the case with radium salts, either taken into the mouth or by injection into the blood stream. Radium, like its fellow members of the second group in the periodic table, especially calcium, can play an important rôle in bodily functions. With its long half-period, it is essentially permanent and elimination is the only means of escape. The rate of elimination has been quantitatively determined. If taken by mouth, 2 to 35 percent remains in the body after the first 5 days, while the amount remaining when injected into the blood stream is 55 to 65 percent. After ten days much of the radium remaining has become fixed in the organs and only about 1 per cent of the remaining radium is eliminated daily. After several years, daily elimination is down to 0.002 to 0.005 percent, for by then the radium is fixed in the bones, bone marrow, spleen and liver. In excretory functions 90 percent of the elimination is in the feces and 10 percent in the urine. The perspiration does not remove any. The radon coming from the radium is largely eliminated from the body as rapidly as formed, thereby reducing the burden on the tissues due to the decay products. Attempts at speeding up the elimination of radium have been made by increasing the calcium metabolism (27). Three cases were fed on parathormone in an intensive régime over a period of some six weeks. These subjects had initially 10, 20 and 40 $\times$ 10^{-6} grams of radium in their bodies. This strenuous treatment was about all the patients could stand and resulted in the elimination of about half the radium. One of these patients subsequently died of cancer of the brain; the other two have so far survived but are in poor health.

The distribution in the body has been determined by radioactive examination of the different organs on autopsy. In the case of a victim who died of drinking activated water, the distribution was as follows (26): Vertebrae 100 parts, jaw 20 parts, femur 27 parts, skull 18 parts, brain 0.4 part, liver 0.06 part, spleen 0.05 part, kidney 0.17 part. In other cases, and where death occurred at different times after ingestion, similar but somewhat different distributions were found.

The detection of the radium in the living person can be easily accomplished, and the assay on bodily parts is easily accomplished by such devices as that which Evans has recently developed (28). There are in California two laboratories capable of making accurate

tests for minute quantities of radioactive material, and several other laboratories in the country can also do this. These are the Departments of Physics at the California Institute of Technology and at the University of California, and the laboratory of Professor Herman Schlundt at the University of Missouri. The detection of radium in the human body can be effected as follows:

1. Radon assay of the air breathed out by the lungs of the patient.
2. A study of the γ ray ionization produced by the patient.
3. The Geiger point counter and Geiger Mueller counters which record the cosmic and γ ray pulses from whatever source.
4. An electroscopic examination of the ashes of the excreta.
5. Radon assay of the urine by the emanation method.
6. Radium assay of the bone parts sloughed off in necrosis.

As was stated before, the serious effects of radium poisoning lag considerably behind the ingestion of the radium. This is because of the time taken for the radium to establish itself permanently and begin its irritating action on the cells causing abnormal behavior. Primarily, bone functions will be affected in view of the concentration of the radium in the bones with the calcium. Thus it is not strange that some of the frequent (22) afflictions caused should be osteomyelitis of the jaw, buccal infections, bone necrosis, slow healing spontaneous fractures of the bones, and bone sarcomas. Owing to the destruction of the centers causing corpuscle formations in the blood, a regenerative anemia much like pernicious anemia is frequently observed, which is accompanied by numerous secondary infections because of lowered resistance. In addition, general ill health, lowered blood pressure and cancer are encountered as frequent consequences.

CONCLUSION

These data clearly show that radium is a most dangerous substance. It is fatal in smaller amounts in the body than perhaps any known substance, 2×10^{-6} grams being known to be fatal. It is an accumulative poison whose ultimate elimination is impossible once it is fixed. It has a relatively delayed action, causing death generally by secondary effects. These secondary diseases present probably the most horrible forms of lingering death known to the medical profession. Some cases of poisoning have resulted from an occupational practice whose danger has been realized and which has been eliminated as a cause. No cases are so far on record that are

known to have been caused by drinking natural waters. Therefore, except for the rare radium plant operatives, who present difficulties, the future problem as regards radium poisoning, especially in water, lies in the practices of the nostrum vendors. These selfish, unscrupulous, and mostly doubtless ignorant men, see a large potential source of revenue in an advertising campaign based on the magic words radium and radioactive foisted on a physically miserable and gullible public. From the more honest vendor who furnishes real value for money received in his radium preparation, thereby killing his victims in a most horrible way, to the frank fraud, who sells a jar containing a brick with as much radium as one ordinarily finds in a granite rock, these men are real menaces to society. It is for the purpose of combating this evil that this article has been prepared for the members of the American Water Works Association, whose function it is to serve the public with the purest and cleanest water available. In conclusion, it might pay to present the results of three analyses of such nostrums recently made by Schlundt (29).

ACTIVATOR	GRAMS Ra IN ACTIVATOR	GRAMS Ra PER LITER WATER	CURIES RADON PER LITER WATER
A. Brick	9.0×10^{-9}		17.5×10^{-12}
B. Carnotite ore	11.2×10^{-6}	6×10^{-9}	77.5×10^{-9}
C. Ra Preparation	31.5×10^{-6}	496×10^{-9}	370×10^{-6}

	RECOMMENDED DAILY DOSE OF RADON IN CURIES	DAILY DOSE OF Ra (GRAMS)	VALUE OF RADIUM IN ACTIVATOR IF EXTRACTED AND PURE
A. Brick	5×10^{-12}		½ cent
B. Carnotite ore	40×10^{-9}	11×10^{-9}	$1.10
C. Ra Preparation	4470×10^{-9}	69×10^{-9}	$3.10

It is at once seen that nostrum A is a simple fraud. Any apparently beneficial effect is thus purely psychological, since the amount of radon taken in is probably not much more than that found in some natural spring waters. It is seen that activator B has 4300 times the radon content of A. In the course of a year, drinking 6 glasses daily as recommended, the user would ingest 4×10^{-6} grams of radium, a fatal amount if most of it were not eliminated in the first 10 days after ingestion. In taking this amount, however, there is no guarantee that some of the α particles of the traces of radium stored in the bones might not find their mark and start cancer cells on their career in the user's body. As seen, nostrum C has 22 million

times the radon that nostrum A has. Two glasses of C daily, as recommended, would, if stored in the body, amount to from 20–25 $\times 10^{-6}$ grams of radium per year. This is at least ten times the lethal amount if stored. Elimination will of course reduce the amount stored by a considerable amount. In addition, this active source loses radium by leaching so that in a year it is reduced to one-fifth its strength. It is seen that this nostrum, while probably honest as far as radium value is concerned, borders closely on the criminally dangerous.

That the vending of such dangerous or fraudulent preparations, with the misinformation accompanying their advertising, should be permitted in such an enlightened country as the United States is almost unbelievable. It is to be hoped that the new food and drugs act as related to advertising, projected by the "New Deal" in the present administration, will prove an effective weapon against such practices in the future. Failing this, the only hope for millions of American citizens lies in the continuous educational campaign in such matters which enlightened public servants, such as the membership of the American Water Works Association, can carry on in the course of their professional duties.

The writer is greatly indebted to Dr. Evans for the use of his notes and bibliography and for the data on ingestion and elimination of radium which was taken from a paper by Evans in the American Journal of Public Health (22).

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HOW MANY ACCOUNTS ARE NECESSARY FOR THE PRACTICAL APPLICATION OF MECHANICAL BILLING EQUIPMENT?

By E. A. Kalkurst

(*Burroughs Adding Machine Company, Detroit, Mich.*)

During the past decade the subject of the application of mechanical equipment in the various phases of utility accounting work has been under discussion at nearly all accounting section meetings of our nationalutility associations. As the customer accounting job is the largest part of utility accounting work, the greater part of these discussions has centered about the application of machines to customer billing. In recent years the amount of customer accounting work in water utilities has steadily increased due to the rapid replacement of flat rates by metered rates, the adoption of more complex rate structures and the additional number of revenue classifications. In many cases also the number of billing periods per year has been multiplied.

The larger water utilities found that considerable saving in clerical personnel could be effected by adopting billing machines and accounting methods made possible by the use of such machines even in the early stages of the development of customer accounting equipment. As the machine manufacturers improved the quality of their product and developed new features which both increased production per bill clerk and furnished additional accounting information as a by-product, the number of water companies using machine methods rapidly increased. Today we find that the majority of water utilities, both municipally and privately owned, are utilizing billing machines to print the bill and post the ledger record or to print the bill only.

In previous discussions among water utility accountants, the principal question seems to have been whether or not the application of machines and machine methods to the billing work would effect a saving in the cost of clerical labor. Although some stress has been laid on the improved product, in a great majority of cases the economic factor seems to have been paramount. The title of this paper, "How Many Accounts Are Necessary for the Practical

Application of Mechanical Billing Equipment?" might be interpreted to mean that we will attempt to show that a certain minimum number of accounts is necessary to justify the application of machines and machine methods on the basis of economic savings. However, we believe that there are other factors which should be considered of equal importance, in determining the answer to this question.

The matter of public relations has become more and more important in the eyes of utility executives during the past few years. This applies equally well to municipally or to privately owned utilities. The question of "How can we improve our public relations?" certainly has become one of the chief subjects of discussion among the officials and employees of water utilities. This question might also be asked in a different way, "How can we improve our contact with our customers?"

If an examination is made into this last thought, what is the principal contact with the customer? Of course, the only continuous personal contact the utility has with its customers is through the meter readers if there are metered customers. Utility officials have been well aware of this fact and have tried to improve the quality of meter reading personnel as well as the methods used in reading. However, the most constant and reliable contact the water company has with its customers is through the water bill. This fact has become more and more recognized during the past few years and the bill is not merely considered as a statement informing the customer of what he owes the company, but is a periodic contact with each customer. Considering it in this light, the bill may either help to make good public relations or become a possible source of public grievance towards the utility.

Bills which are neat, accurate, distinctive and clear help to produce good-will and offset to some degree the antagonistic feeling which any communication requiring a cash expenditure naturally produces in most people. Just as the general appearance, size, space for information, etc., have caused many water utilities to swing away from the postcard and adopt the paper form of bill, many companies have made the question of neatness, accuracy and legibility the ruling factors in adopting machines to do the billing, rather than basing their judgment on cost of labor and material alone. This has been especially true in the case of small companies and we find companies ranging from 200 to 2,000 meters or bills changing from hand to machine methods.

All information which might reasonably be of interest to the customer should be shown on the bill. This fact is recognized by nearly all water utilities and usually as much of this information as possible is printed upon the bill by the printer. If it is desirable that part of the information be handled by the printer, the remainder certainly should be printed upon the bill by some type of mechanical equipment if the general effect of the bill is to be pleasing. The portion of the information most generally printed on all bills is the name and address of the utility, location of collection offices and such other general information as may be desired.

Nearly all utilities print the name and address of the customer, together with an account number or other account identification, by means of some form of addressing equipment. The cost of such equipment is usually very low. Its use is most advantageous since uniformity of name, address, account number, etc., are obtained once a stencil or plate is prepared. The other factors usually shown on the bill are the date of the bill, the date of the expiration of the discount, the date of the present and previous meter readings, total consumption, the consumption at each rate, gross bill, net bill, unpaid balance and the grand total. This information may be entered upon the bill by hand, typewriter or billing machines. Hand written bills are seldom neat in appearance and the writing is sometimes done so hurriedly that the figures are not legible. Printed figures are certainly neater and more desirable and although this effect could be obtained by using a typewriter, a billing machine which both prints and accumulates different factors for means of proving the accuracy of the work is always more economical than the use of a typewriter in typing the bills and then proving the accuracy of the entries at a separate operation.

The entries made on the customer's bill which should be proved for accuracy are the meter readings, the consumption, the break-down of the consumption, if any, the gross amount of the bill, the amount of the discount, the net, unpaid balances and the grand total. In addition, there may be other entries, such as service charges and special debits, which should also be proved. The larger types of billing machines furnish as a by-product, accumulations which enable the accounting department to prove the accuracy of the entries very quickly and easily. Although on some of the smaller types of machines, which might be used on a small number of accounts, all these factors may not be proved as quickly, proof is

nevertheless effected much more efficiently and easily than if billing machines were not used.

Considered from an accounting standpoint, the accuracy of the computations of both the amount of water used and the extension of the rate should most certainly be proved regardless of whether the hand or machine method is used. Because of the great amount of work involved, in actual practice many water companies using hand methods do not secure an absolute proof of the correctness of revenue. Probably nothing is more destructive to the maintenance of good public relations than the rendering of bills which may contain errors.

If we assume that good accounting practice demands that the customer's bill be made accurately, in making a study of the cost of customer billing in a water utility having a small number of accounts, this factor must be taken into consideration.

Where the month end peak is experienced, the meter reading routine should be scheduled to spread the work evenly through the period to provide the proper billing cycle. The average month consists of twenty-one working days. Therefore, the entire schedule of continuous reading, billing and discount days should be based on that fact. This allows an even distribution of work throughout the month and also results in a more uniform collection of cash, preventing peak loads on the last discount dates. Each meter reading route consists of enough meter reading sheets to constitute a day's work. If domestic and commercial meters are included in the same route, the meter reading sheets may be of different colors to identify the service. The color used should correspond to the colors of the bills and ledgers. The variation of color acts as a signal to billers, tellers, sorters and posters.

The bills of a section or a district should be scheduled so that the last discount day will fall on the same day of the month each billing period. In case of this day falling on a Sunday or a holiday, the discount is allowed on the following day. This arrangement will tend to improve collections because if the bill is received regularly provision will be made to take care of the charges.

The practice of obtaining a trial balance on all of the accounts at the end of the month is a big task, regardless of whether or not machines are used, and it results in a large number of items being carried forward which are not due or payable on account of the bills being issued during the last half of the month. This peak load may be eliminated by balancing each district as a unit. Instead of doing

all the work in a few days at the end of the month, it is spread out over the month.

A control ledger is maintained for each district, showing the previous month's uncollected balance, the current debit, current credit and the amount outstanding. The unpaid amounts as obtained by this trial balance should all be transcribed to the current month's bills and the total of arrears billed, balanced with the control. This method tends to localize errors and speeds up delivery of the bills, as each district may be balanced as billed.

Some small water companies may have the idea that mechanical billing equipment will cost them far more than they feel they can afford to invest. However, the mechanical equipment manufacturers have made great improvements in machines adapted for the customer accounting work in small utilities and a wide range of models makes it comparatively easy to select the type of machine suitable to handle the work to be done and at a cost that no water utility can afford to ignore, considering the benefits to be gained, both from the standpoint of accounting and public relations.

Consideration must also be given to the fact that the accounting machine manufacturers have developed machines which will not only handle the customer accounting work in the small utility, but will also handle other classes of accounting work, such as payroll, material and supplies, accounts payable, general records and reports.

This same type of machine is very popular for municipal accounting, as both the water and tax billing may be done by the same clerical force. In addition, assessment records, budgetary accounting, etc., may be handled with the same machine.

EXAMPLES OF EQUIPMENT

It may be of interest to give some concrete examples of just what the cost is for mechanical equipment to do this work in the smaller water utility. For this purpose, reference to some of the different types of machines which one equipment manufacturer has developed for handling customer and other accounting work is made.

For utilities having from 200 to about 1,000 accounts per month, a small type of billing machine has been developed which will produce a very neat and accurate bill at a cost to the utility of about $1.00 per week for the machine. This cost is based on a seven-year amortization of original purchase price, together with interest on the investment and maintenance charges during this period. In addi-

tion, when this machine is not being utilized on billing work, it may be used for general figure work of all kinds.

Another type of accounting machine will handle from 200 to about 2,000 bills a month at a cost of less than $2.00 per week for the machine. Still another type of machine which not only will handle the billing work on several thousand accounts, but will also do all the general accounting work in a small water utility, or the tax, assessment and budgetary accounting of a municipality, can be obtained at a cost of about $5.00 per week.

The fourth type of machine which would be principally used for customer accounting purposes, will handle efficiently from 2,000 to in excess of 20,000 bills per month according to the accounting system used and the number of customers involved. The cost of this machine would be about $5.00 per week.

When a proper analysis of the work to be done in the office of any specific utility is made, the proper machine for the job can be easily determined.

Considering the very small cost for proper machine equipment, entirely disregarding the possibility of actual savings being effected, it is apparent that almost any water utility can well afford to utilize modern mechanical equipment and advanced accounting methods on this important work. If the application of billing machines will aid the customer accounting department in decreasing the number of customers' complaints and tend to improve the public relations, most certainly the great majority of water works officials would be justified in spending a few cents per day to achieve these results. Cannot the answer to the question asked in the subject of this paper be properly answered by stating that, regardless of the number of customer accounts, no water utility can afford to ignore the advantages of machine-made customer records and bills?

(*Presented before the Southeastern Section meeting, April 5, 1933.*)

DISCUSSION

MR. GIBSON, Manager, Water Department, Charleston, S. C.: I take a little consolation in that fifteen years ago when I went to Charleston I asked the Burroughs Adding Machine Company to give me the kind of machine they are now supplying and they told me they had a machine in process of making but they would not sell it then. I bought a makeshift and have been using it for fifteen years and the

Burroughs man is trying to get me to scrap it. I am now seriously considering putting in a machine that will make out our bills, giving us the date, the present reading, the previous reading, the difference between the present and the previous reading, the amount in dollars and cents, the amount making up the minimum, or service charge, and at the same time print that information on the ledger card—that, as I understand it, is all done with one operation. At the end of the day we will be able with that information tabulated to know the exact amount in dollars and cents of revenue billed, the quantity of water billed and the amount that has been received.

We get that same information today, but it is by a process of one or two steps at a time and we do not record on the ledger card with the machine. It is done by hand and, of course, is subject to the possibility of error in the transposition of the bill to the ledger card and getting the wrong card with the bills, but at the end of the day we can now tell you the total amount of water, the total receipts for the day, the total charges for the day and the balance due from our customers. To do that we have to close our office about an hour before the office force leaves. With this new billing machine I do not expect to cut out a clerk, but I hope to be able to keep the office open possibly a half or three quarters of an hour longer and in the summer time that means a considerable improvement, for to close the office at four-thirty or five when the average person does not think of going home in Charleston until about six-thirty is quite an item.

Miss STONALAND, Water and Light Department, Thomasville, Ga.: I should like to ask if the billing with the ledger card is more generally used or the billing without the use of the ledger card, billing in triplicate?

MR. KALKURST: We find it is about evenly divided. About half of the utilities use what is known as the stub plan and do not post any ledger cards. The machine really bills the stubs automatically, one stub remains on the bill and goes to the customer and the customer returns that with his check. That becomes the cashier's receipt and the accounting department simply files this cashier's receipt, that same stub, in the paid file. Under that plan the only open accounts on the ledger are those that are in the file, so when you look for the bills that are in arrears you do not have to go through the ledger, but just take out the bills left in the file.

MISS STONALAND: They do not use the ledger card if they have the stub plan?

MR. KALKURST: No, in the stub plan they just file the stub.

MISS STONALAND: In Thomasville we use the two bills and the stub and find it very satisfactory.

MR. KALKURST: It may interest you to know that we just recently secured an order from the City of Atlanta for machines that will perform the details I have outlined. If there are any errors in the readings, which are copied from the meter book, the machine will detect them and it will not complete the bill. It absolutely will not clear until the error is corrected.

MR. GIBSON: We never have used the stub system at Charleston. I have never been won over to that method. I find in my relations with the public that there is nothing that will so completely and satisfactorily end a dispute as to a water bill than to lay before the customer his past record. We remember the bad things, the pleasant things of life usually fade out of the picture. The consumer gets a bill and it looks high to him. I have had them come to me again and again and say, "Mr. Gibson, I never had a bill like that in all my thirty years dealing with the Charleston water works." There is no use telling him he has without showing him. I call for the bookkeeper in charge of the ledger cards and ask him for the account of Mr. Doe and then I say to him, "Mr. Doe, I just cannot square your statement with your record." I lay the card before him and there he will see where his bill started up gradually—$3.00, $3.25, $3.50, $4.00 and $4.50 and now it has gotten to $6.00, or more, but there is his record. Then I have had that same customer say, "Well I'm sorry I made that statement but I really didn't think I ever had had such a bill before in my life—I just can't understand it." With that history spread out before him it shows that he has possibly had an incipient leak that started twelve months before and he paid no attention to it until it reached this point. For that one reason alone I have always looked askance at the stub system, for you do not get the information without going through the records and you can not do that without losing a whole lot of time.

MR. SCHUMPERT, Light and Water Superintendent, Newberry, S. C.: I should like to ask Mr. Gibson what would be his objection to using the meter book, with the whole year's record before you. No matter what rate change we make during the year the consumption is there and, after all, that's what you have to show the consumer. I am surprised to know that the machine we have is like Atlanta's. I did not know we were that nearly up to date. I prefer the meter book so I will have the entire consumption right on down the line. The rates do not have anything to do with it.

MR. GIBSON: Our meter reader reads the meter only. He does no clerical work whatever. He turns the meter reading in on the card and no reductions are made. He may have a certain number of rereads. Perhaps a complaint is made where the bill seems high, but we depend entirely upon the Burroughs machine to do our addition and subtraction. We compare these bills with the meter reader's card and if the bill is in line it is sent out. If it is not, he is sent out for a reread. Our meter readers are very efficient and seldom make a mistake. They are not allowed to do any clerical work whatever. If a customer asks them to give them their reading for a month they are permitted to do that but they make no bills.

MR. KALKURST: The rereads referred to could probably be eliminated if the reader made the deduction at the time he read the meter.

MR. GIBSON: All our meters are at the sidewalks and 99 percent of the time he never could see anybody but the colored cook. It would be a waste of time and labor to try to explain to anybody in the house that the bill had gone up. Human nature is not such that you can tell a customer when he asks you to reread his meter that you did reread it and give it to the cook. That will not satisfy him. Our meter readers are efficient and they have no responsibility except to read the meters.

MR. SCHUMPERT: We just happen to have the electric lights in connection with the water and we read the water meter and then go around to the rear to get the light reading. I have instructed my boys to try to find leaks. If they can find the leak and convince them before they leave that is certainly a big help. However, if there is a mistake made in the reading, the machine will not clear out until

it is corrected. I have seen our men work a half hour to make it clear but it will not. When our readers make a mistake we do not rub it out, we leave that as a knot on the log for him to look at for twelve months. If it is his mistake it is a knot there for him to see. Your reader does not subtract?

MR. GIBSON: No, for he has about two hundred meters to read and he has to keep hustling to get them back in to us and not slow down all the work.

MR. FINDLAY, Secretary, Board of Water Commissioners, Macon, Ga.: At Macon we use a Burroughs billing machine in connection with an addressograph and we print the bills in duplicate. They show the present and past reading, the number of cubic feet, the rate and the amount. If that bill is paid on time we tear off the delinquent notice and if it is not paid on time we have have that delinquent notice already made out and it goes out by mail or hand in a few days. The billing clerk makes the bills from the meter readers route book. The meter reader is not allowed to discuss with the customer anything about the reading of that meter or any complaint. He is permitted to tell the customer to take the matter up with the office. If the meter reader has to look up leaks and have discussions with the customers the route book is naturally delayed in coming into the office and everything is thrown behind. Furthermore, if he is allowed to look after complaints, if he wanted to he could go to a baseball game and say he was late because he had so many complaints to see about. In our office, if a man wants to know his record all we do is turn to the consumers ledger and get out his account. We can show him in chronological order his monthly bill for a period of four or five years. It is a very simple method and very efficient.

MR. LITTLE, Secretary, American Water Works Association, Rochester, N. Y.: I do not want to enter into the controversy as to whether the reader should subtract or not but I want to congratulate the reader of the paper. Ordinarily we are afraid to have a paper by a representative of manufacturers of water works equipment because it will be dry and a sales paper, but the discussion of this paper shows it brought something more to us. As regards the billing machine, I am very much in favor of it. I remember when I was a small boy I wanted a bicycle very much and I think that should be the way with

every superintendent who has not a billing machine. He ought to want it and not be content until he gets it. I am going to ask perhaps a very foolish question of the author of that paper, that is, are there very many water plants that are otherwise well managed and well run that still have the old fashioned way of keeping books?

MR. KALKURST: I regret to say there are quite a lot of them. Perhaps we have not proven good enough salesmen to sell them. There are quite a number that are still making up the bills in pencil and using two or three clerks to do the work where one machine and one clerk could do it all very nicely. The operation of the machine, although looked upon as complicated, is really very simple.

CHAIRMAN POWELL: At Griffin, Georgia, we use the ledger sheet and we clear out on the 30th of November. The sheets go to the cashier's window. If the customer says, "We never have had any such bill," the cashier simply pulls out the entire record and shows it to him. If I have a meter reader who will tell the customer what the bill is I will discharge him. He can tell them to call the office, but he can not tell them a thing about the bill. If any bill looks excessive we notify the customer immediately that the bill looks high and to have the plumbing examined.

LIME SLUDGE AND ITS DISPOSAL

By Harry T. Campion

(*Superintendent of Filtration, Grand Rapids, Mich.*)

Softening of the hard water of the Grand River by lime precipitation has been practiced locally for twenty-one years. Soda ash is not used. By lime treatment, the original hardness of the water is reduced 60 percent.

The sedimentation of the precipitated solids, turbidity, etc. is accomplished at Grand Rapids in four large basins, having a total capacity of 5.3 million gallons. Two of these, numbers 1 and 2, were constructed in 1912 and are covered. The other two, numbers 3 and 4, were constructed twelve years later and are open. The basins are equipped with valves which allow any to be operated separately, in pairs, or all four in series. General practice is to admit treated water to numbers 1 and 3 and take settled water off numbers 2 and 4. The bulk of the sludge settles in 1 and 3. All basins were originally of the plain baffled type.

In line with current practice, the Grand Rapids' Plant has been and still is dumping its waste sludge back into the river about 500 feet downstream from the raw water intake. The drain or sewer which carries the sludge discharges at a point which was probably at one time one of the rapids. The river bed at this point is 600 feet wide. Before the plant was built, the river channel was deepened on the west side, causing a fairly deep channel about 200 feet wide through which passed all or nearly all of the dry weather flow. This left shallow water on the east or plant side of the river, and it was into this shallow water that the sludge was discharged. As the deposits filled up the river bed, the drain or sewer was gradually extended.

Extremely low water stages during the summer of 1930 presented a serious situation. Lime deposit extended two-thirds of the way across the river. There was no flow at all across the deposits and as the summer advanced the flow of sludge was forced or carried upstream and into the plant intake, causing disagreeable tastes in the water. The obvious remedy was to again extend the drain, which

was hurriedly done, and from this time (1930) sludge has been discharged on the west side of the river. One might say we have been ponding our sludge and the ponds were full.

One of the reasons for thus filling up the river was that sludge was dumped out in such large quantities. Basins were cleaned when full or nearly full of the sludge, upwards of 400 tons. Due to high summer pumpages of 1930 and 1931 the time of cleaning could not be picked.

Complaints about this river pollution were numerous and officials began to hear about the apparent value of the material we were wasting. A number of schemes for reclamation were suggested.

Obviously the first thing to be done was to equip one or more of the basins with machinery for the continuous removing of the sludge. The high estimated cost of Clarifier machinery in 1931 resulted in investigations of other schemes for removing the sludge. Plans for a moving bridge type similar to those in use at sewage plants to be placed on basin No. 3 were drawn up in 1932. High costs and possible trouble with patents prevented the adoption of this scheme.

In 1932 about 500 tons of the sludge were pumped from the settling basins to the sewage treatment works for study as to its effect on sewage sludge. The results of this experiment are described by "Eldridge" in Book No. 40 of the Michigan Engineering Station. According to this report, handling of the lime sludge was feasible, but at considerable extra cost to the sewage treatment works.

Early in 1933 both the Dorr Company and the Link Belt Company submitted proposals which involved changes in basin No. 3, and the installation of sludge removal machinery. The proposal of the Dorr Company was approved, an appropriation was obtained and the work was completed for about $18,000,000. The basin was placed in service on May 22, 1933. Briefly, changes in this basin consisted in conversion of a plain settling basin, roughly 123 feet by 141 feet in area, containing 5 baffles, to a clarifier 123 feet square, and a narrow chamber designated the carbonation chamber 123 feet by 15 feet in area. In the squared section the floor was filled in, sloped toward the center and equipped with a revolving drum and scraper arm having a sweep of 122 feet. The extensive corners were sloped to a pitch of 2 inches per foot, and equipped with perforated pipe for flushing sludge deposits down to within reach of the scrapers. Operation of this clarifier has been satisfactory during the summer, a sludge having a moisture content of 85 percent by weight has been readily obtained.

Observations of the effect on the river of the discharge of sludge

from this clarifier indicates that there is considerable improvement. Plans for equipping basin No. 1 (one of the covered basins) with sludge removal machinery are now under consideration, and should this be carried out it is doubtful if the discharge of sludge will in the future create a local nuisance.

METHODS OF DISPOSAL

During the program of basin improvements methods of reclamation or disposal of the sludge, other than discharging into the river, were investigated.

Schemes now in use or proposed are as follows:

1. Transporting in wet state to low ground for filling, or ponding reclamation.
2. Partial or complete drying for use as a soil sweetener.
3. Calcining and using again for softening.
4. Use as a filler in paints, putty, wall board, etc.

As far as ponding is concerned, we had, as before mentioned, created extensive deposits in the river, which deposits were quite dry on top during the summers of 1930 and 1931. In spite of extensive unemployment, no interest could be developed in the material as it lay in the river.

Located, as is the Grand Rapids' plant, the possibility of doing any extensive filling is remote. Fills could be made along the river, but they would be upstream from the intake, with danger of supernatant water causing tastes in the plant water supply.

As a soil sweetener, the dried or partially dried sludge is a high grade marl equal for farm purposes to the ground limestone sold generally. During the greater part of the year the sludge is clean, is light cream in color when dry, or at 15 percent moisture, and analyzes as follows:

	percent
Calcium as CaO	46.1
Magnesium as MgO	5.2
CO_2	36.2
Silica	4.1
Alumina as Al_2O_3	1.6
Ferric Oxide	0.6
Organic Matter	1.7

Calcium calculated as carbonate would be 82.3 percent.

Local dealers in agricultural lime have stated a willingness to handle the sludge if it was dried to about 15 percent moisture.

Dewatering

It is possible in summer to dry the sludge in drying beds to 50 percent water. With good drainage we have reduced the moisture content from 85 to 33 percent moisture in seven days. Air drying in any quantity, however, is impractical at the Grand Rapids' plant.

The first step in dewatering is to reduce the material to a condition where it can be handled, i.e. to a 60 percent moisture cake. Two methods for this dewatering have been tried, i.e. by centrifuge and by vacuum filter.

Sometime ago a barrel of the sludge was shipped to the Sharples Company for investigation, and based on experiments made at that time, the following was submitted. "The net production of a 48-inch horizontal centrifuge would be 340 pounds per hour, on a dry basis, with an average lime cake produced containing 66 percent moisture. To handle ten tons of sludge daily, three of the 48-inch centrifugals would be required."

An interesting feature about the cake produced by the centrifuge is that the centrifugal motion stratifies the product. We find that after whirling the sludge a layer of wet slimy ooze, containing nearly all of the organic matter, lies above the lime cake proper. This wet ooze would show probably 80 percent water, while a cake from under this layer was obtained which ran 47 percent water. It is possible to decant this layer of ooze by means of one of the decanter tubes. This ability to remove the organic matter might be of use in producing a cake for use in certain fillers. For agricultural uses, however, the entire cake would be used, and at this time it does not seem that the centrifuge produces cake in sufficient quantity to make reclamation profitable.

By means of vacuum filters, similar in design to the model supplied by the Oliver United Filters, the wet sludge can be reduced to a 60 percent moisture cake. The process is automatic and not expensive. Figures supplied by the Oliver United Filters are as follows:

Estimated cost of machinery for handling 10 tons (dry basis) of lime sludge per day, $6,325.00. This includes one Oliver Filter, vacuum pump, receiver and all appurtenances.

Estimated cost of producing 10 tons of filter cake of approximately 60 percent water, 83 cents per ton.

The second step in the drying would be reduction from a 60 percent cake to approximate dryness, or to such dryness as would be required by the market. A cake which would pass through the hammer mill

at the sewage treatment plant was easily produced by drying the 60 percent cake in air during the past summer.

For production drying of the cake, either a rotary drier of a furnace similar to the Nichols Herreshoff furnace could be used, and its use could be tied in with either plant heating or the burning of coke for the CO_2 production. Figures supplied by the Harddinge Company indicate that drying by a rotary drier could be accomplished at about 95 cents per ton, including interest and depreciation charges.

Marketing of the dried product would present a difficult, but not an impossible problem.

The Kent County Farm Bureau reports that 1700 tons of ground limestone were sold in this county during 1932. The amount of arm used was tremendous and figures for this are not available. Price of the ground limestone was $2.50 per ton on cars.

Local interest in the use of the dried sludge is apparent from the calls which come from local residents who own farms in the country adjacent to Grand Rapids. There is a slight tendency of the sludge when mixed with sandy soil to assist in retaining moisture in the ground, which fact, if properly played up, would constitute effective advertising. The experience of the local sewage treatment works in marketing its dried sludge as fertilizer is interesting. In 1932, 500 tons were sold, which figure would have been greater had not the supply run out. This was done with no advertising other than some postal cards.

Calcination

Calcination consists in taking the dried or partially dried sludge, heating it in a retort or kiln to about 1400°F., which temperature drives off the carbon dioxide leaving the calcium as the oxide, or unslaked lime. Recovery by calcination is reported to be in operation at the plant of the South-End Water Works Company, Southend, England. Reburning of the sludge at Columbus, Ohio, was proposed by Hoover in 1915. The plant was never built.

Reburning of the sludge has been proposed by several local investigators from time to time. Some agitation for this project was started by a local engineer this spring, who stated that if such recovery were made no more new lime would have to be bought for local use, in fact, we could supply a large part of the local trade.

To obtain some data on the effects on the lime of repeated uses for softening followed by reburning, a quantity of the dried sludge was calcined in a small laboratory furnace. The lime so obtained was

used again in softening the water, the sludge caught, dried and reburned and thus passed through five cycles.

Tests for water soluble calcium oxide by the usual methods (Ellms and Sugan) were made with the following results:

	CaO percent
Original Lime:	89.0
First sludge reburned	78.5
Second sludge reburned	71.0
Third sludge reburned	64.0
Fourth sludge reburned	56.2

The limes obtained showed increases in magnesium content and other ingredients than calcium, as follows:

	Magnesium as oxide percent
First sludge reburned	6.8
Second sludge reburned	No figures obtained
Third sludge reburned	11.9
Fourth sludge reburned	17.4

An interesting feature is that more lime is produced than was applied originally in the softening. In the treatment with the 1st reburned sludge, 38 grams of the 78.5 percent lime was added to 60 gallons of water (alum treated) from which 95 grams of dry sludge were obtained. These 95 grams of sludge burned to 52.3 grams of 71.0 percent lime. Then 38 grams of the 71 percent lime were added to 60 gallons of alum treated water, producing 92 grams of sludge which burned to 50.6 grams of 64 percent lime; and so on. Each cycle produces more lime, but of lower water soluble calcium oxide content.

Local specifications call for a lime having a CaO content of not lower than 82 percent, which eliminates the possibility of the reburned material being used in the local plant.

From time to time suggestions have been made that the dried or partially dried sludge could be used as a filler in paints, putty, insect sprays, etc. As far as the writer has been able to ascertain, very little progress has been made in this direction.

As a filler for paints, objection has been made to its content of organic matter. This could be overcome by using the centrifugal method of dewatering and simply discarding the layer of organic matter which overlies the cake in the centrifuge bowl.

Plaster and insulating board

For over a year local interested parties have been studying the possibility of using the sludge as a filler in the manufacture of plaster board and insulating board.

The growth of the plaster board industry, even though handicapped by the slump in the building trades, has been remarkable. Investigation of cheap, but efficient fillers, will be unquestionably increased due to the fact that the gypsum or calcium sulphate now used as a filler is relatively high in price.

Samples of plaster board were made from lime sludge produced at this plant and a cheap grade of paper. Information comes to the writer that this material has been submitted to the leading testing laboratories, from which very favorable reports have been received; that it has been set up in rooms for examination under varying conditions of heat and moisture in competition with standard grades of plaster board. The method of manufacture has been patented and plans for production have been drawn up.

This material weighs about 1600 pounds per thousand square foot of surface. Two-thirds of its weight consists of the filler. The whole idea in the investigation revolves around the expectation of getting the sludge (in wet condition) for very little, if any, cost, using other local products and manufacturing as near as possible to the base of the filler and other ingredients.

In view of the fact that the development of this project is private and in a highly competitive field, publication of a large amount of available data can not be made at this time, but the writer is assured that the project has merit.

CONCLUSIONS

In the absence of a definite order from some supervisory agency to cease river pollution, the only motive which will justify actual reclamation of the sludge will be that of financial profit. It is the writer's opinion that dewatering to a salable product can be made at a cost which should add little, if anything, to the cost of water. Revenue from a private venture would be pure velvet at this time. If efforts to interest private capital in the use of sludge for the manufacture of building material do not materialize in the near future, it is the plan locally to dry and bag sufficient of the sludge to sound out the possibility of marketing the material in competition with limestone now being used, to arrange for demonstration and to advertise the product.

(*Presented before the Central States Section meeting, September 22, 1933.*)

THE HOWARD BEND PLANT OF THE ST. LOUIS WATER WORKS

By C. M. Daily

(Water Commissioner, St. Louis, Mo.)

The age of the St. Louis Water Works is over a century. It has been continually growing from the time it was purchased by the City in 1834 to the present. In the winters of 1911 and 1912, due to an ice blockade, the water fell to an unusually low elevation and it was very difficult to get water into the old intake in the Mississippi River and keep the suction well free from ice. For several days a water famine threatened. It is a catastrophe or a near catastrophe of this kind that awakens a community to the danger of using an old plant beyond its capacity before necessary funds are made available for the construction of a new plant or an addition to the old one.

In 1914 the construction of a new intake tower and tunnel at the Chain of Rocks and a filter plant were started. They were completed in 1915.

A survey and preliminary designs were made for increasing the capacity of the Chain of Rocks Plant to 320 m.g.d. A survey and plans were also made for a plant of 160 m.g.d. on the Missouri River at Howard Bend. The difficulty of keeping the old Chain of Rocks Plant in service while constructing a new plant, together with the fact that Howard Bend was closer to the western part of the City where the greater development in residential districts is taking place, caused the site at Howard Bend to be chosen as the best location.

In 1917 the extensions to the Chain of Rocks Plant were completed and during the next 4 or 5 years, while the war was in progress, no further developments were made. In 1923 a bond issue of $12,000,000.00 was authorized for a new water works. Before any of the bonds were sold a contract was let and work begun on river improvement at Howard Bend. This work was paid for out of the general revenue and later on the money was refunded from the bond issue to the water works revenue.

In 1923 the main channel of the river was along the northern bank

and a series of 24 dikes were constructed to divert the channel to the southern bank of the Missouri River where it is at the present time. The cost of the river work amounted to $670,000.00. The Government paid $18,369.00 of the amount and since 1928 the United States Government has spent probably twice that amount in regulation works both above and below our present plant, which insures an abundant water supply as long as the channel is maintained in its present location.

PRELIMINARY STUDIES

Before beginning the work at Howard Bend Plant it was necessary to determine the elevation and character of the underlying rock. An attempt was made to locate the rock in 1913 and, after spending several weeks, the data obtained showed the rock or something hard, anyway from 37 to 67 feet below the surface of the ground. An auger was used for the boring. These data were looked upon as very unreliable and in 1923, work sounding for rock by jetting a 2½-inch pipe was started. The boiler and water pump were set at the river bank, and a pressure of about 160 pounds at the pump was maintained. A 2½-inch was jetted to rock in 12 places. The nozzle was removed from the end of the pipe after reaching rock and the pipe left in place and a diamond core drill working inside the pipe, obtained samples of the rock in three places. Samples of the rock were taken to a depth of about 15 feet and all samples showed a good quality of limestone.

One peculiar incident occurred in jetting these pipes. When a depth of about 80 feet was reached it was necessary to disconnect the hose 4 to 5 feet above the ground and put on another section of pipe. When this was done water flowed out of the pipe, in one case as long as a half-hour, much to the amazement of the crew. Several hypotheses have been presented to explain this phenomenon. Probably one of the following two is the correct answer: Somewhere in this particular stratum of gravel there was a gas pocket and after jetting the pipe, through a layer of gumbo, the gas was compressed and when the pressure from the hose was released the expanding gas forced the water out of the pipe. The other is similar; the pipe extended through a very tough gumbo and it acted as a hugh hydraulic jack which lifted the surrounding ground a very small amount. When the pressure was released the ground settled in the back and forced the water out of the pipe.

INTAKE AND ENGINE PITS

In 1924 a contract for an intake and high and low service engine pits were let and work began. This work involved a large amount of cofferdam work. The Water Department specifications were drawn and plans were made for a cellular cofferdam. The Water Department, not the contractor, assumed the responsibility for its successful operation. The work was carried on very successfully and the only trouble encountered was when the contractor, in his anxiety to complete the work, lowered the water in the cofferdam which was forbidden by his contract, causing the sand to flow under the cofferdam and into the pit. After this experience no further trouble was experienced in keeping the water inside the cofferdam at the same elevation as the river.

After the excavation was made, which was done by dredging, 538 48-foot reinforced concrete piles were driven to rock inside the cofferdam and the low service engine pit. After the piles were driven, a 5-foot seal of concrete was poured through a tremie over the entire bottom and after setting sufficiently the water was pumped out, and except for a few places around the piling where the concrete did not make a tight connection, there were no leaks. These leaks were easily remedied by driving White Pine wedges into the openings. After completing the sub-base of the engine pit, the reinforced concrete bottom, 4 feet thick, was poured and the walls completed without any difficulty.

In the high service engine pit a different design of cofferdam was used. It was made of straight 12-inch sheet piling weighing 37.2 pound per foot and the tops anchored back into the soil to the deadmen. Five hundred and fifty-five piles 68-feet long were driven to bed rock inside the cofferdam. No particular difficulty was experienced with this cofferdam excepting where the contractor attempted to use less anchorage than was necessary to hold the piling, or where heavy loads were imposed around the cofferdam.

ROADS

Before any building was commenced on this project, it was necessary to build a highway from the plant to the hard road. The first road was constructed from Hog Hollow Road to the plant, a distance of about a mile and one-half. Later on this road was connected to the Little Lake Road, a distance of about two and one-half miles.

A railway switch was made connecting to the Rock Island main line. The Water Department did all the switching for the contractors engaged in constructing the new plant, using a 15-ton gasoline locomotive.

STEEL PRESSURE MAIN

In 1925 a contract was let for laying a 60- to 62-inch steel pressure main from the plant to the reservoir at Stacy Park and from the reservoir at Stacy Park into the City, a distance of approximately 16 miles, at a cost of $1,930,729.00. There was also a short piece of 48-inch steel pipe, layed from Concourse Drive to Macklind Ave. This work was carried on without any difficulty, excepting on two or three occasions a floating of the pipe occurred, once on Clayton Road when a county water main broke and filled the ditch and again along the Rock Island Railroad where it was floated two or three times due to flood water.

The unusually wet Spring of 1927 caused the water to flow into the unprotected end of the steel conduit and fill a long stretch with mud. This mud was later washed out by the contractor at his own expense.

Where the pressure was greatest on this line a welded steel pipe was used for the longitudinal joints and a riveted joint for circumferential joints in the field. Pipes delivered were about 30 feet in length.

RESERVOIR

In 1925 a contract was let for Stacy Park Reservoir at a cost of $1,160,808.00. This reservoir is several miles from a railroad. A ready mix concrete plant was erected at the railroad and concrete hauled in small trucks with hopper mounted on the chassis. A row of sheet piling was driven all around the footing down to hardpan. This reservoir has a capacity of 100,000,000 gallons and is covered by a 4-inch slab resting on columns placed $16\frac{2}{3}$ feet apart, with reinforcing in both directions. It is not intended that a heavy load should go over this roof. However, a driver, in his haste to deliver a load of reinforcing and get home, drove over the roof with a 7 ton load without causing any damage. Airplanes have also picked this spot as a good place to land and several of them have landed on the roof. This practice, however, has been discouraged and no planes have tried to land on the roof in the last few years.

FILTER PLANT

In 1926 a contract was let for a Filter Plant with a capacity of 80 m.g.d. at a cost of $715,903.00. Work was carried on very successfully. The filter plant was designed to have a gutter on two sides making the 4,000,000 gallon unit in one bed and not in two beds as it is in the old plant at the Chain of Rocks. The underdrain system is main pipe and laterals spaced 12 inch center to center, with $\frac{3}{8}$-inch orifices on the under side of the laterals. The plant was designed to have 18 inches of gravel and 29 inches of sand. Mississippi River sand was specified. In the construction of the work this was changed and instead of using Mississippi River sand, Ottawa sand was substituted. No change was made in the size of the gravel. Some difficulty has been experienced with piling up of the gravel and most of this can be attributed to packing of the sand and side movement of wash water, coupled with faulty washing of the filters. At the present time the filters are being overhauled and cellular bottoms made of Cypress are being installed to prevent the wash water from passing laterally through the large gravel to any weak spot which may occur in the sand bed.

In 1927 a contract was let for sedimentation and coagulation basins. In 1928 a contract was let for a secondary coagulation basin. For the primary sedimentation and coagulation basins steel sheet piles 14 feet long were driven under the footings of all the walls. These piles were recovered from the sheet piling cofferdam of the intake and engine pits.

In the primary sedimentation basins mechanisms were installed for continuously removing the sediment. This equipment cost, roughly, $150,000.00. The first year it failed to operate during the severe winter months due to ice. The basins having only an 8-inch sewer pipe outlet are not easily cleaned by sluicing.

Assuming this equipment will last 20 years and the annuity to replace it in 20 years, plus the interest of 4 percent, will amount to $11,037.00 per year, a sum far in excess of the cost of cleaning the basin by sluicing and washing with hose.

In 1927 a contract was let for a clear water reservoir located north of the filter plant. This was completed without any particular difficulty.

The filter controllers, manufactured by the Builders Iron Foundry, are similar to those used at the Chain of Rocks. They were purchased by the City and set by the contractor.

PUMPING EQUIPMENT

The pumping equipment consists of two 60 m.g. steam turbine-driven pumps and one 120 m.g. pump. The high service pumps are two 60 m.g. steam turbine-driven pumps. They were installed and put in operation in 1929 and final test and payment were made in July, 1933. The penalty and bonus practically balanced. The average efficiencies of the low service pumps are for the 120 m.g., 134.26 and for the 60 m.g., 120.189 foot pounds per B.t.u. used. The efficiency of the high service pumps was 166.291 foot pounds per B.t.u. used.

The boiler equipment consists of four 650 H. P. Heine boilers. The coal is stored in bunkers overhead the boilers and feeds directly into the stokers.

(*Presented before the Missouri Valley Section meeting, October 27, 1933.*)

THE HULL WATERWORKS SYSTEM

By Theodore Lanctot

(City Engineer, Hull, Province of Quebec, Canada)

At the great fire of 1886 when over 150 buildings, including the post office, were razed to the grounds, fire protection was given through the services of a voluntary brigade, who had as equipment hand pumps, and the bucket line. The drinking water was also at the time sold and delivered by the barrel. The City Council realizing the necessity of avoiding further conflagrations, and also of supplying its population with a more potable and drinking water, authorized Mr. Sortees, civil engineer, to prepare plans immediately for the construction of a water works pumping and distribution system.

The first birth year of Hull's waterworks system was 1887. A steam pumping system was installed, and the pumps used were of the Duplex Compound Condensing type and purchased from the Knowles Steam Pump Works. The distribution system comprised a 12-inch pipe main line with 8, 6, 5 and 4-inch branches. From 1887 to 1902, additions and extensions were made to the pumping and distribution systems. In 1902 with the expansion of the City territory and its increase in population, the old steam pumping plant became inadequate. The City was therefore compelled to locate a new site and to modernize its pumping equipment.

PUMPING EQUIPMENT

The present location of the pumping station was chosen. The initial steam plant was maintained merely as a standby, and a completely new system was installed at the new plant which comprised:

Two sets of Knowles Horizontal Triplex pumps double acting with a capacity of 3,000,000 gals. each per 24 hours and driven by two 48-inch McCormick turbines. In 1908 one set of Hamilton horizontal Triplex pumps, double acting, was added with a capacity of 6,000,000 gals. per 24 hours and driven by a 56-inch Hamilton Turbine. The water power to operate these turbines was supplied by

the Brewery Creek, branching off the Ottawa River. We then had a total pumping capacity of 15,000,000 gals. per 24 hours including the steam plant stand-by.

In 1915, due to pumping requirements two DeLaval centrifugal pumps of 8,000,000 g.p.d. operated by two 300 H.P. motors were installed. The power was purchased from the Ottawa and Hull Power Company, on the basis of one-cent per k.w.h. for power consumed, plux a fixed assessment of $3.00 per H.P. per annum for a stand-by 300 H.P. These DeLaval pumps, when working in parallel against a head of 173 feet, would deliver 16,000,000 g.p.d. or 8,000,000 g.p.d. when working in series against a head of 325 feet. With these additional pumps we increased our pumping capacity from 15,000,000 to 28,000,000 gallons of which 20,000,000 were available in case of fire.

In 1916, wishing to harness as much energy as could be developed in the Brewery Creek, the City authorized the construction of a 750 K.V.A. generator to supply the necessary power to operate the electrical pumps and the system of street lighting. In 1920 the contract with the Power Company for the stand-by was renewed for 500 H.P. at the same conditions as in 1915. In 1921 overheating of the 300 H.P. motors caused much trouble, but it was remedied at once by replacing them by two 450 H.P. In 1924, our contract with the Power Company took a sudden jump and we were compelled to pay $18.00 per annum per H.P. for 500 H.P. or $9000.00 a year fixed charges. In addition to this extra cost of stand-by, the cost of maintenance and repairs of our hydraulic pumps was also rapidly increasing, and their efficiency was gradually decreasing. Under these circumstances, it was necessary to improve the system so as to reduce these expenses.

In 1927–28, the following changes were made at the pumping station. We discarded the two 3,000,000 gallons triplex pumps, and replaced them with two centrifugal pumps of 4,800,000 g.p.d. at 80 pounds pressure and the Hamilton Triplex pump was also replaced by a centrifugal pump of 8,000,000 g.p.d. at 80 pounds pressure. All these pumps were operated by the old water wheels. We also added an electrical booster pump of 8,000,000 g.p.d. to our electrical operated turbines, so as to be able to raise the pressure from 65 to 95 pounds on one pump, without having to start a second 450 H.P. motor. By these changes we increased our pumping capacity to 32,600,000 g.p.d.

Thought was also given to replace the electric by a gasoline standby, so as to reduce the fixed charge of $9000.00 to a minimum. After much discussion with the local power company we obtained a very favorable contract which eliminated the question of a gasoline standby. We are now paying $1,725.00 for 575 H.P. as compared to $9,000.00 for 500 H.P.

The yearly saving of $7,275.00 more than compensates for the interest and sinking fund on the capital investment brought along by these modern improvements. We have also electrified all our main valves. In the old days some of our 20- and 30-inch valves required two and three men and took from 10 to 15 minutes to operate. Now they are operated by one man, through a switchboard.

With this pumping system we have been able to establish a demarcation between the upper and lower levels of the City. Previous to this installation the pumping was done through the distribution system at large, and if the pressure had to be raised in the lower level of the city, this high pressure was being maintained throughout the system. With the new system, pressure can be raised through one level, without affecting the pressure of the other, through the manipulation of one valve.

With the present pumping system we are complying with practically all recommendations made by the Canadian Fire Underwriters Association, and have obtained a very substantial reduction in fire rates just after the completion of our plant reconstruction.

The total book assets of the water works system in 1932 based upon an appraisal in 1919 and compiled from year to year is as follows:

Lands and buildings	$227,222.36
Pumping system and hydro plant	$168,795.85
Distribution system, mains, valves, hydrants, etc	$1,087,615.60
	$1,483,633.81

This total is exclusive of depreciation which amounted to $216,592.35 up to 1932. The total debt of the water works system is $1,262,480.00, which compares favorably with our assets of $1,483,633.81.

The total number of house connections in 1932 were 5543, of which 5409 were in service.

WATER RATES

A fixed charge of $8.00 is made per service on a municipal assessment of $900.00 or less.

For an assessment over $900.00 to $100,000.00 a fixed charge of $10.00 and one half cent for each dollar of assessment are imposed and added to the cost of the service. For example, an assessment of $75,000.00 would pay a water tax of $385.00.

For an assessment over $100.000.00 an extra $4.00 per $1000.00 or part of $1000.00 is added. An assessment of $250,000.00 would pay a rate of $1,110.00. On every vacant lot where the main pipe is laid, the rate is one half the above mentioned rate.

On every lot and construction located within a radius of 250 yards from the water main the rate is one fourth of the regular price.

(*Presented before the Canadian Section meeting, March 23, 1933.*)

THE OTTAWA WATER WORKS SYSTEM

By A. D. Stalker

(Assistant Engineer, Water Works, Ottawa, Ontario, Canada)

The Ottawa River has always been the source from which the city has drawn its water supply. This river has a catchment area, above the water works intake, of about 35,000 square miles, and has an average flow of over 30,000 c.f.s., the minimum flow being more than half this amount. The physical and chemical characteristics of Ottawa River water have been described in a paper[1] by H. P. Stockwell. It is sufficient to say here that the water in its raw state leaves much to be desired as a public supply of first class quality.

From 1872 to 1912, water flowed by gravity through an intake pipe having its inlet at a point in the river adjacent to Lemieux Island, under Nepean Bay, to Queen Street pumping station, where water driven pumps pumped it to the distribution system, without treatment of any kind. During this period the death rate due to typhoid fever ranged from 20 to 42 per 100,000 of population per year.

The fact that Ottawa River water in its raw state was not good enough for drinking purposes was recognized long ago. From 1910 onwards, numerous reports on various improvement schemes were prepared and submitted to council, some of them by the most outstanding experts on either side of the Atlantic. None of the schemes reported on, got past the report stage, all being voted down when submitted to the ratepayers as money by-laws.

The city suffered an epidemic of typhoid fever in 1912 and 1913, the death rate from this disease rising to 84 per 100,000 of population in 1912, and 87 in 1913. Investigation showed this epidemic to be due to a break in the intake pipe through which contamination from a faulty sewer entered the water supply. The epidemic, however, added strength to the agitation for an improved water supply.

Disinfection was started in the spring of 1913, bleach solution being used as the agent. At about the same time a low-lift pumping sta-

[1] Journal, August, 1933, page 1088.

tion was erected and equipped at the inlet end of the intake, and from this time onward the intake pipes were kept under pressure to prevent infiltration of contamination between the intake inlet and Queen Street pumping station. In 1918, a high-lift pumping station, constructed on Lemieux Island and equipped with electrically operated pumps, was completed and put into service. Water from this station passes through two 51-inch lock-bar steel pipes that cross the channel separating the island from the Ontario shore on a reinforced concrete bridge, erected for the joint purpose of carrying the pipes and serving as a means of access to the island, and continue overland to the distribution system, "A" line tying in at the corner of Laurier Avenue and Bronson Avenue. "B" line at this time was blanked at the corner of Champagne Avenue and Wellington Street, and left for future extension.

In the mean time, Joseph Race, who was the city bacteriologist at the time, had been experimenting on the use of chloramine as a sterilizing agent. He had used it experimentally on the city water supply at different times between 1915 and 1917, and from 1917 on it was used continuously. The typhoid death rate from the time sterilization was started until 1917 ranged from 10 to 15 per 100,000 of population. During the time chloramine was being used the death rate never exceeded 3 per 100,000.

In 1922, "B" line of the overland pipe was extended and connected to both the suction and discharge sides of Queen Street pumping station, the flow to either side being controlled by electrically operated valves. Alterations were made to the low lift pumping layout at Lemieux Island that enabled us to discharge water under low head to "B" line. With this arrangement it was possible to deliver water under high pressure to the distribution system through either "A" or "B" lines, or to send it by an all land route, through "B" line, to the suction side of Queen Street pumping station.

The use of the high-lift pumping station on Lemieux Island and the overland pipes eliminated the danger of pollution entering the water supply from Nepean Bay. We still depended on sterilization to keep the water safe, and for sterilization we were using equipment that was installed in the first instance as a temporary expedient only. Nothing was done to clarify the water. It was still objectionable in appearance, and when the condition of the raw water necessitated heavy doses of chloramine, it had a disagreeable taste.

EDUCATIONAL CAMPAIGN

From 1920 W. E. MacDonald, city water works engineer, had been carrying on an educational campaign with the object of impressing on the people of Ottawa the fact that their line of defence against epidemics of water-borne diseases was not sufficiently strong. This campaign was persistently continued from 1920 until 1928, by which time public opinion appeared to have become strongly in favour of immediate action in initiating works that would place the water supplied the citizens above reproach. Early in 1928 A. M. Maccallum, then commissioner of works for Ottawa, was instructed by the city council to review all of the reports on improved water supply previously submitted, to examine into any available source not previously reported on, and to recommend the scheme he considered best suited to the City's need. After a thorough examination of the whole question by Mr. Macallum and Mr. MacDonald, Mr. Macallum reported in favour of constructing a water purification plant of the rapid sand type on Lemieux Island, to treat Ottawa River water. Mr. MacDonald particularly stressed the advisability of first constructing a trial plant and operating it sufficiently long to gather data pertaining to the treatment of Ottawa River water under all conditions.

This project was submitted to the rate payers as a money by-law at the election held in December, 1928. During the month prior to the election, Mr. MacDonald and other members of the Water Department addressed numerous meetings, explaining the proposed work in detail, and on this occasion the by-law was given a substantial majority.

EXPERIMENTAL PLANT

Immediately following the favorable vote, the firm of Gore, Nasmith and Storrie, consulting engineers, Toronto, were retained first to design and operate the trial plant, and when the necessary data had been collected, to design and supervise the construction of the main plant. The trial plant was completed in February, 1929, experimental work was started in March and carried on continuously until September, under Dr. G. G. Nasmith. This phase of the work was described in a very interesting paper[2] read by Dr. Nasmith before

[2] Journal, August, 1930, page 1017.

the American Water Works Association at the convention in St. Louis in June, 1930.

The data collected during the period the trial plant was operating proved of inestimable value to the consulting engineers when designing the main plant, and also enabled our staff to become familiar with problems that they would meet in operating the main plant later. One point strikingly demonstrated was the extreme delicacy of the floc formed in treating Ottawa River water with alum. It is probably not going too far to say that the secret of successfully treating this water hinges on a proper appreciation of this fact. In this plant, the absence of mechanical agitators of any kind, the type of mixing employed, the large size of the settled water conduits, and the low-head losses in the filters are some of the results attributable to the exceptional fragility of the floc.

CONTRACTS AWARDED

The work connected with the construction of the water purification plant included a 60-feet extension to the pumping station, a chemical building adjoining the pumping station, and the purification plant proper, which is a structure covering an area 384 feet 6 inches by 242 feet. Clearing the site, grubbing, all excavation and backfilling, and all work in connection with tying in the new work with the existing plant, as well as any alterations that had to be made in the existing plant itself, was undertaken by civic forces. The work in connection with constructing and equipping the new plant was divided into 15 contracts, which were let as follows:

Contract No. 1—Purification plant sub-structure, Ross Meagher Ltd., Ottawa.

Contract No. 2—Purification plant super-structure, Rose Meagher Ltd., Ottawa.

Contract No. 3—Filter equipment and appurtenances, W. J. Westaway Co. Ltd., Hamilton.

Contract No. 4—Pumping equipment, Canadian Allis-Chalmers Ltd., Toronto.

Contract No. 5—Pumping Station Extension & Chemical Building, H. Dagenais Ltd., Ottawa.

Contract No. 6—Cast Iron Pipe and Special Castings, John T. Hepburn, Ltd., Toronto.

Contract No. 7—Gate valves, check valves and sluice gate, the General Supply Co. of Canada Ltd., Ottawa.

Contract No. 8—Automatic valves, W. J. Westaway Co. Ltd., Hamilton.

Contract No. 9—Venturi Meters and Water Level Controller, the General Supply Co. of Canada Ltd., Ottawa.

Contract No. 10—Pneumatic Conveying Equipment, the General Supply Co., of Canada Ltd., Ottawa.

Contract No. 11—Alum and lime dry feeding equipment, the General Supply Co. of Canada Ltd., Ottawa.

Contract No. 12—Chlorinators, W. J. Westaway Co., Ltd., Hamilton.

Contract No. 13—Insulating pipe, Robt. T. Purvis & Co., Toronto.

Contract No. 14—Electrical equipment, Fred A. Wilson, Ottawa.

Contract No. 15—Filling material, Mahoney & Rich, Ottawa.

The supervision of the construction work was under the consulting engineers and the engineering branch of the Ottawa Water Department jointly. William Gore or William Storrie inspected the work frequently during its progress, while the Water Department maintained a staff of engineers and inspectors on the job constantly. The control of concrete was by the water cement ratio method, all mixes being designed by our own staff. Proportioning was by weight of dry material and gallons of water. As the contractors were being paid for concrete exclusive of cement by the cubic yard, and for cement by the bag, there was no object in their trying to skimp in the quantity of cement used. Test cylinders were taken throughout the construction period at the rate of about one for each hundred yards of concrete placed. The fact that the cylinders consistently broke just above the specified figure, and seldom sufficiently far above to indicate wasteful use of cement, speaks volumes for the excellence of the work of the staff in charge of concrete control. Construction work was started in May, 1930, and completed in April, 1932.

Water from the new plant was first turned into the distribution system on April (1932). On the following day one of our staff hung a crepe on the door of the old "dope house." It is fitting that we should speak only good of the departed. A glance at the typhoid death rate chart will show that the old plant did keep the water safe. The trials and tribulations of our staff in keeping it functioning far beyond its capacity, and for a period of time far longer than was originally intended, can be better imagined than described.

The new plant was officially opened by the Governor General of Canada on April 30, 1932.

WATER PURIFICATION PLANT

The quantity of chemicals required to treat Ottawa River water satisfactorily is comparatively high, consequently storage and handling facilities had to be provided that are unusual for a plant of the capacity of this one. There are four storage bins, two for alum and two for lime, each one of which is capable of holding six car loads. A railway siding runs into the chemical building, and chemicals are lifted from the cars to the top of the storage bins by means of "Dracco" pneumatic conveying and distributing equipment. The chemicals feed by gravity from the bins to the dry feeders, which are placed directly underneath, there being one dry feeder for each bin.

Raw water enters the suction well of the pump house extension, which houses the low lift pumps, through a port on the north side just west of where the extension joins the original structure. The suction well under the extension is separated from that under the old portion by a steel and concrete diaphragm, on which is installed a 72- by 84-inch sluice gate. The diaphragm is 12 inches by 17 feet 6 inches by 10½ inches, and placing it and making it water tight proved difficult, as the rock through which the channel is cut is at this point very seamy, and unwatering was troublesome.

Alum feed process

The alum dosage is added to the water just before it reaches the suctions of the low-lift pumps. The water is pumped by pumps designed to deliver 17½ m.g.d. against a head of 47½ ft., three of which have been installed. Automatic cone valves are installed on the discharge nozzles of these pumps. The water next passes through a Venturi meter which in addition to measuring the quantity passing it also controls the alum dosage. Just down-stream from the Venturi throat is a hydraulic valve controlling the flow of water into the plant. The valve is operated by a Builders Iron Foundry pendulum unit water level controller, equipped with an increasometer. This unit is designed to maintain the water level in the mixing chambers within 1-inch above or below a given point. The water next passes through a 3-way branch and is distributed to three stilling chambers. It rises to the top of the stilling chamber, and enters the first of the

mixing basins. The type of mixing in use here was evolved by Mr. Gore after considerable experimental work in the trial plant. The mixing basins are so designed as to cause a gentle spiral flow through the four units, down in the first, up in the second, down in the third and up in the fourth. Experiment showed that the mixing given by this method is the most vigorous that could be used on this water without a harmful effect on the floc. The chambers are 30 ft. deep, and the water takes 40 minutes to flow through the battery of four when the plant is operating at the standard rate of 108 million Imperial gallons per acre of sand area per day. The water next passes to the settling basins through a distributing weir that tends to change the spiral flow to a flow straight down the tank, and also allows the water to enter the tank in such a way as to minimize the possibility of setting up currents or eddies.

There are three settling basins, each 301 ft. long, 30 ft. wide and 30 ft. deep. An interesting structural feature is the fact that the settling basin and reservoir wall bases are sunk into channels three feet deep cut in the solid rock on which the plant is built. No explosives were used in excavating these channels, holes being drilled as close together as possible along the sides, and the rock removed by means of plugs and feathers. This was expensive work, but insured rigid shoulders for the wall bases to butt against.

There are no baffles of any description in the settling basins, and that a properly formed floc will settle satisfactorily without baffling arrangements is proven by the fact that we have had as high as 90 percent of the floc settling out. The period of retention when operating at standard rates is three hours and twenty minutes.

The settled water is drawn off the top of the settling basin at the south end, and enters the top section of a double decked conduit, which runs across the full width of the plant, along the east end of the east filters and along the west end of the west filters. The bottom section of the conduit carries the used wash water and the water wasted in cleaning out the settling basins to a 54-inch concrete drain pipe through which it flows to the south channel of the river.

Ten filters in use

Water enters the filters directly from the settled water conduit through 15- by 42-inch sluice gates. The filters each have a sand area of 26 by 56 feet, and are of 3½-m.g.d. capacity. Ten filters are equipped and in use, but the foundation work is in for an additional

14 units and the plant can be easily and economically extended until it reaches a capacity of 84 m.g.d.

The underdrain system consists of 4-inch cast-iron laterals spaced at 12-inch centres, and having tobin bronze bushed orifices $\frac{3}{4}$-inch in diameter on the under side, also spaced at 12-inch centres. The water collected in the laterals flows to the centre line of the filter bed and passes through a 4- by 4- by 6-inch tee into a 39- by 36-inch concrete conduit cast on the under side of the filter floor, from which it flows through a Builders Iron Foundry pendulum unit rate controller, and is discharged into the filtered water reservoir.

Wash water system

The wash-water tank is located above the mixing chambers. It is a concrete tank, with a capacity of 250,000 gallons, and as it was essential that it be not only absolutely water tight, but that it be constructed in such a manner as to obviate the possibility of condensation on the under side (which forms the ceiling of the mixing chamber room) a more detailed description of its construction might prove worth while. The tank is really two tanks, one fitting into the other, and separated from each other by waterproofing material. The concrete forming the outer tank was first placed, and the inner surfaces of the walls and floor rubbed smooth. Over the whole surface, floor and walls, was placed a layer of No. 50 asbestos waterproofing felt, each strip being lapped 3 inches and sealed with a heavy coating of waterproofing cement. The whole surface was next mopped with waterproofing cement, using 30 pounds to 100 square ft., and while the cement was still hot a layer of Johns-Manville asphalt saturated fabric was imbedded in it, laid at right angles to the felt, and the edges lapping 3-inch. The surface was again mopped with waterproofing cement, and a layer of asbestos felt weighing 15 pounds per 100 square ft. was imbedded in it, laid at right angles to the saturated fabric, and the edges lapping 3-inches, and then over that was mopped another coating of waterproofing cement, using 25 pounds to 100 square ft., on the floor, over the membrane waterproofing a layer of heavy waxed paper was laid dry, and on this was placed a mastic coating to protect the membrane. The concrete forming the tank was then placed directly against the membrane waterproofing. The result was a perfectly water-tight tank, and we have never noticed the slightest sign of condensation on the ceiling of the mixing chamber room.

The two wash-water pumps, which are of 5-m.g.d. capacity, are automatic, being controlled by a float in the wash-water tank. The same float governs the bulls-eye lights on the dial panel at the north end of the operating gallery, which indicate to the filter operator the elevation of the water in the wash-water tank. There are three bulls-eye lights, colored green, amber and red respectively. As the contacts are set at present, the green light showing alone indicates a full tank. When a filter is being washed, the amber light comes on with the green, and when the green light goes out, leaving the amber light on alone, the quantity of water required for backwashing has passed through the bed. The contact that starts the pump is made just as the green light goes out. If it is required to wash two beds before filling, the second wash is started with the amber light alone showing, the amber and red showing as the washing is going on, the end point being when the amber goes off, leaving the red alone showing. In this second case, an adjustment is made to have the pump starting contact made as the amber light goes off.

The operating gallery differs from most plants, in that it is separated from the filters by a glass screen. This feature allows us to heat the gallery to comfortable room temperature in winter, while the area over the filters and mixing chambers is kept just above the freezing point. The gallery forms a corridor between the east and west filters, and the dignified proportions and high class finish of this portion of the structure makes it exceptionally pleasing in appearance. The floor is of Roman travertine, and the dado, which reaches to the top of the operating tables, is of marble. The operating tables, which are part of the structure, are of marble similar to that in the dado. The entrance to the gallery is through bronze doors at the north end, and above these doors is a marble dial panel on which are the bulls-eye lights previously mentioned, a dial indicating the rate at which water is leaving the filtered water reservoir, a dial indicating the elevation of water in the reservoir, and an electrically operated clock.

The pipe gallery is not as congested as is frequently the case, owing to the fact that the settled water conduit and the conduit conveying the used wash water from the filters are at the east and west ends of the filters, as previously described. The lay-out of pipes, valves and controlling apparatus is such as to allow of replacements or repairs being made with very little difficulty.

Filtered water reservoir

The filtered water reservoir, located under the filters, both present and future, is of six million gallons capacity. The plant is at such an elevation that the water in the reservoir at and above the two-third full mark will flow to Queen Street pumping station by gravity. This provides us with a valuable stand-by in the event of electrical power trouble, and in order to take full advantage of this, it is our practice to operate with the reservoir full at all times. The plant is equipped with an automatic master control, operated from a float in the reservoir. As the reservoir drops, the rate of filtration of all ten filters is increased by the master control, and the reverse when the reservoir rises.

Water from the reservoir flow to the pumping station through a 66-inch pipe line, in which is inserted a Venturi tube, which measures the effluent and controls the dosage of lime and chlorine. The branch feeding "B" line of the overland pipes is taken off just inside the pumping station, and the line continues on to feed the Lemieux Island high-lift pumps. Normally two-thirds to three-quarters of the water is pumped to the distribution system by the Lemieux Island high-lift pumps, the balance being handled by the water driven pumps at Queen Street.

Stand-by units

For stand-by purposes we have installed a 35-m.g.d. low-lift pump driven by a 430-h.p. Diesel engine, and a small turbo-generator set for generating power for lighting. In the event of interruption in the supply of electrical energy, a valve on the line feeding the turbo-generator opens, allowing a small quantity of water from the mixing chambers to flow back through the turbine that drives the generator. Sufficient power is generated to light the plant and to operate the chemical feeders. The Queen Street station picks up the pumping load, and assuming that the reservoir was full when the power interruption came, the water in the top third would be sufficient to supply the city for a little over two hours, at the present rate of consumption. If the trouble is something that cannot be immediately overcome, the Diesel-driven pump is started and the water in the reservoir is replenished as it is drawn off. With the turbo-generator set to provide us with power for lighting the plant and feeding the chemicals, the Diesel-driven unit to pump the water into the plant, the water going through the purifying process to the reser-

voir and from the reservoir to Queen Street pumping station by gravity, and the water-driven pumps at Queen Street pumping to the distribution system, we are able to keep the city supplied with water indefinitely without any electrical power available.

COST

The plant is so designed as to allow of economical extension until it reaches an ultimate capacity of 84 m.g.d. Parts of the works were installed in such a manner as to serve for the 84-m.g.d. plant without any change. In breaking down the cost to cost per million gallons, I have used the 84-m.g.d. figure in cases where no changes will be necessary in extending the plant, and 35-m.g.d. for those parts that will have to be extended. The total cost was $1,481,098.77. The cost per million imperial gallons was $38,466.55.

WATER WORKS FINANCING

By G. P. Gordon

(Commissioner of Finance, Ottawa, Can.)

Water plants and systems may be operated either as private corporations under franchise, or as public utilities under municipal control. Each system has its protagonists, and arguments may be advanced as to the peculiar advantage of each. One writer has concisely summed up these arguments as follows.

"Private management allows: (a) better control of employees; (b) the payment of salaries somewhat commensurate with the work performed, and hence the employment of those more nearly suited to fill important positions; and (c) prompter action for meeting new conditions of service.

"The municipally operated department can: (a) secure funds at a low rate of interest; (b) operate with expense for legal services and for litigation reduced to a minimum; and (c) build structures of a more permanent nature than would be possible for a company to construct that operates under a limited franchise."

With a system operating under private ownership the object is to produce and supply a commodity at a cost less than the price at which it is sold to the consumer, thus creating a surplus of revenue over expenditure from which to establish a reserve to maintain the capital assets against depreciation and obsolescence, and to return an adequate rate of interest on the capital invested in the enterprise. With a system operating as a public utility under municipal ownership the object is to produce a commodity at the lowest possible cost compatible with the maintaining and operating the system on a sound basis of efficiency and supplying that commodity to the consumers (the ratepayers) at cost. Owing, however, to the interlocking of the operating of a municipally owned water works system with other municipal services true cost is seldom established. Other factors also enter into the situation, both in operating charges and methods of revenue collection, which mitigate against all consumers paying equitably for the water they consume and on a cost basis. These will be discussed later.

Owing to the nature of the operations involved in connection with a water works system, the universality of the use of the commodity supplied, the method of its distribution, and the close relationship that exists between it and the functions of certain civic services, as e.g., fire fighting, street flushing, etc., it is but a normal situation that it should be operated municipally as a public utility; and so do we find most water works systems operated. Not only do many municipalities operate their own water works for the purpose of supplying the needs of their own ratepayers and other uses within their confines, but also take care of the requirements of contiguous municipalities with surplus water they may have available, thus creating an extra source of revenue, as well as decreasing costs by increased production.

While the supplying of water is today a normal function of most urban municipalities the financing and accounting of this service should be kept entirely separate and distinct from the financing and accounting of the regular and other general services undertaken by a municipality, such as the expenditures for education, fire protection, police protection, social service, health administration, public hospitalisation, recreation services, maintenance of streets, sewers, etc. These latter are met, in the main, along with certain miscellaneous revenue derived from other sources, by levy based on property and income assessment, such levy being established through a tax rate struck which will bear the necessary relationship to total assessment requisite to raise, in taxation, the estimated amount of a balanced budget to take care, for the year, of the appropriations set to meet expenditures for the various public services and including the amounts to be provided for interest on and principal of debenture debt. The surplus or deficit on operating, as the case may be, will be, after all adjustments have been made, simply the result of whether income has exceeded expenditure or vice versa, such balance, favorable or adverse, to be absorbed in adjusting the budget for subsequent levy.

In the case of the municipally operated water works system, the modus operandi is entirely different. As a public utility it must stand on its own feet and be operated on its own profit and loss basis. The structure of its accounts should be on a similar basis to that of a privately operated corporation, with this exception, that no portion of surplus is distributed in dividends as earnings of capital invested. The revenue derived from the sale and distribution of

water, on whatever basis may be established, is not from taxation but direct charges for a commodity supplied and services rendered. Water rates, in this respect, differ essentially from the levy on property and income assessment for other and regular municipal services, or, to put it otherwise, water rates are not taxes in the true sense of the word. It might be that we can derive some small degree of comfort from this, when, in these days of increasing taxation and decreasing incomes, we find our dictionary, in addition to giving the regular meaning of tax as: "a compulsory contribution levied upon persons, property or business for the support of government," also informs us that it means: "a disagreeable or burdensome duty or charge, an exaction, an oppressive demand," interpretations to which, today, I am sure, we will all agree; or when we remember that the word tax is derived from tactum, the supine of the Latin verb tangere, to touch, which would lead us to consider that a tax is a species of touch, the public instrument that touches the private purse.

FINANCING NEW WORK

As we have already stated, in the matter of establishing and maintaining a water works system, from the point of view of financing, the necessary money must be provided for (a) capital expenditure, and (b) operation and maintenance. As a public utility, municipally owned, capital may be raised in either of two ways, or by a combination of both (a) by debenture issue, and (or) (b) by the capitalization of surplus earnings. Probably, in the case of a publicly owned system, there is too great a tendency to make use only of the former method. While this always appears, at the time of expenditure, the easier and the simpler plan to follow, and the path of least resistance, it is the more expensive in the ultimate issue, as not only is there the feature of discount on the sale of the debentures, and other possible costs, to be taken into consideration, but there is the interest to be met on the borrowing to the maturity of the bonds as well. I do not suggest, however, that it is good policy, or fair, equitable or just, that major expenditures for structures or developments, the normal life of which would extend over a long period of years, should be met from surplus. Such policy would be an undue burden on the present rate payers, and those who, through excessive charges had been called upon to create the necessary surplus earnings. But what I want to emphasize is this, that public debt should not be

increased, as in recent years has been too much the tendency, by only borrowing for improvements and developments. By following such a policy, present costs may be kept down, and as a result, the water rates to the public, but what has been borrowed must be repaid, not only in principal sum, but also with interest as well. Such payments, in subsequent years, represent fixed charges which become an integral part of cost, and as the cost of production increases as a result, the rate to the consumer will correspondingly increase. This may easily become a serious situation, and in many phases of public administration has so become in recent years. Present borrowings for betterments and developments, if not undertaken on the basis of a sound and reasonable policy may easily become an undue burden on posterity. I would therefore strongly advocate that the administration of our municipally owned water works systems be so carried out that current rates for water supplied be such, that not only are all costs adequately covered thereby, but that also they be such that reasonable surpluses be created from which expenditures for normal development be met, other than large capital undertakings, the lifetime of which will extend over a long, or considerably long, period of years. Such a procedure would combine, in my opinion, in a sane and sound manner, a pay-as-you-go policy as far as reasonably practicable, and that of adequately and properly funding projects and developments of greater magnitude. The carrying out of a policy such as this would tend to stabilize costs over greater periods of time, would be equitable and just, and eminently fair both to the present rate payer and the rate payer of the years to come. Our trust is not for ourselves alone, but for posterity as well.

The ease with which a sound municipality can borrow at comparatively low rates of interest on a favorable market has, no doubt, been responsible to no small extent for the large public debts of so many of our modern cities, a very considerable portion of which has been to take care of our water works systems. We should never, even in our most enthusiastic moments, when considering the advantages and benefits that will accrue from our large capital expenditures forget how costly a matter public borrowing is. If we would just remember that a straight term 5 percent debenture issue for 20 years for $100,000.00 will cost exactly $200,000.00 in interest and repayment of principal alone by maturity, it would help very much to temper our judgment before undertaking the commitment.

The rate at which money can be raised by debenture issue by a

municipality for water works purposes will depend on the credit of the municipality. The water works officials should see to it, therefore, that the system is run on the most efficient and economic basis that no unsatisfactory financial conditions may arise concerning it, which might tend to affect adversely the credit of the municipality.

Serial or sinking fund bonds

In raising capital funds for the development or betterment of the water works system the debentures may be of the serial or the sinking fund type. Generally speaking, the former method is distinctly in favor today, although many of the earlier issues are of the sinking fund type, and market conditions may be, at times, such that it may be advisable to float this type of bond. With a serial issue the problem of meeting the principal of the bonds at maturity is comparatively simple, those falling due each year being met at redemption date by the appropriation set aside in the year's estimates for that purpose. The procedure in connection with the retiring of a sinking fund issue is somewhat more involved. The bylaw authorising the flotation of the issue states the amount to be set aside, in an investment fund, each year which, at a predetermined rate of interest, will be adequate to retire the issue at maturity date. Sound judgment must be used in the investment of the sinking fund. In Canada such funds may be invested only in such securities as are permissible under the Trustee Act. It would be a matter of sound policy, however, if investments for sinking fund account were made only in bonds of direct or guaranteed obligations of the federal or provincial governments of the Dominion, and the highest grade of municipals, the investments being so made so as to have diversification. It is also important that the securities held for sinking fund be closely matched as to date of maturity of the debentures of the municipality against which they are held. To fail to do so might easily result in considerable loss to the fund in that, to meet maturing obligations, securities held might require to be sold in an adverse market considerably below their par value, as well as the price at which they were purchased.

It is of equal importance that securities held for sinking fund be redeemable in the same currency as the debentures against which they are held. Failure to do this may result in heavy loss as has actually occurred in many instances during the last two years as a consequence of the depreciation of the Canadian dollar in relation

to New York funds. Most Canadian municipalities of any considerable size have bonds falling due in sterling or New York funds, or both, as well as Canadian funds. In order to obviate the vagaries of exchange, it is therefore obvious how important a matter it is that a municipality have its sinking fund investments redeemable in the same currency as the obligations of the municipality, against which they are matched, fall due.

As already explained a water works system, operated municipally, must stand on its own profit and loss basis. Appropriations for maintenance and operation are not derived from the general fund, nor is any part of the revenue credited thereto. In the financial statements of the municipality the water works system must show its own balance sheet and its profit and loss statement. Its various assets and liabilities are set up, dissociated from the other activities of the Corporation. All charges relative to the system arising direct from the water works department, and the proper proportion of services rendered by other civic departments on behalf of the system, should be charged to the water works accounts, thus setting up the proper relative charges and establishing correct costs. On the other hand, the system should be credited, not only with the revenue derived from water rates, but also for all services rendered to other civic departments, as well as any miscellaneous revenue that might accrue otherwise. This is sound theory, but in practice it is only carried out in varying degree. Generally, and in most instances, the system bears practically all the cost which should be properly allocated to it. This will include the direct cost of the water works department, comprising pumping, filtration, and distribution of the water to points of ultimate use, and all the activities, administrative and otherwise connected therewith, to which will be added proportionate charges from the Engineering, the Treasury, the Collector's and other departments for services rendered and costs undertaken on behalf of the water works system. In addition, the system will bear its appropriations to meet debt charges in connection with its debenture issues, interest on bank overdraft, if any, insurance premiums, etc. To meet these costs of maintenance and operating, rates for water supplied by the system, along with any miscellaneous revenue which may accrue, must be set. These should be fully adequate not only to meet all costs of operating, but also to establish and maintain a sufficient reserve to meet unforseen increased costs in any year or years, thus obviating the unsatisfactory condition of

having to be continually changing rates, particularly in the direction of increase. To follow a sound economic policy, sufficient surplus should be created to carry out a certain amount of capital work from earnings.

Included in revenue earned by the water works system should be not only the proceeds from water rates, and other earnings from outside sources, but adequate credits for water used by the Corporation itself in the maintaining of its other civic functions. As near as possible such water should be paid for at actual cost, and rates set accordingly. Credits in this connection with relative charges against the departments would be for water used for fire fighting purposes (established by a rate set per hydrant), street flushing, requirements of civic buildings, etc. Such a basis of establishing water works revenue is theoretically sound, but, in practice, as already stated, is not always followed. Conditions may exist where it is not expedient, or even fair and just to the majority of the ratepayers to carry out such theory fully in practice, as in a city with a very large proportion of tax exempt property including institutions which are heavy users of water. In such cases where the city credits the water works system for the water used for civic purposes, the appropriations of the departments using such water are charged with the cost, and the general tax levy is increased accordingly. No part of this is, of course, borne by the tax exempt property, which, on the other hand derives further potential advantage therefrom, and, if by the increased revenue, it is possible to reduce water rates, such tax exempt property would be contributing even less to the upkeep of civic administration. A city council may then, where there is a large proportion of tax exempt property within the municipality, using very considerable quantities of water, decide to make no charge for water used by the various departments. While, of course, we cannot endorse such practice from the point of view of perfectly good theory, or of sound water works operating, we can see, from the view point of the interest of the rate payers at large, the reasonableness of the argument.

Rate structure

The major part of the revenue of the water works system is derived from the rate payers, i.e., the citizens at large, the property holders, institutions, and business and commercial establishments. As already stated, the basis of the rates set on which consumers pay

should be as nearly as possible actual cost, and sufficient to set up a reasonable reserve to take care of certain normal improvements and betterments. The only equitable system for the charging of water supplied is by metering, the consumer then paying exactly for what he uses, just as he would for any other commodity. Few cities, however, are metered 100 percent. In different municipalities different methods of establishing water charges are followed, the two commonest being by actual metering and by fixed rates on property assessment. Generally all commercial establishments, apartment houses, institutions and other large consumers are metered, but, commonly, ordinary dwellings are not, the basis of fixed rates on property assessment being used. Where this latter system is followed, although manifestly economically unsound, inequitable, and conducive to waste, it is extremely difficult to have it changed to the fair, equitable and economic method of metering. In recent years, in progressive municipalities, much improvement has taken place in this direction, but the administrative boards of many municipalities lack the courage to effect what they know is a sound and rational change because of the opposition of the rate payers themselves. It is both economically and morally sound that a man should pay for exactly what he receives, not for more and not for less. In the matter of water consumption metering would establish this. It would also accomplish another most desirable thing, the elimination of a tremendous amount of waste, such elimination tending greatly to reduce costs. No gas or electric company, publicly or privately owned, would dream of distributing or selling its output on other than a regulated tariff, according to metered consumption. For any such utility to do otherwise would spell disaster. No doubt, as municipal boards and councils become more alive to public duty, and ratepayers to their own real interests, the situation will change with reference to the method of charging for water consumed, supplied by a publicly owned water works system, and the future will eventually see, uniformly adopted, the plan of charging by regulated tariff according to metered consumption.

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ADSORPTION OF COPPER SULFATE BY ALUMINUM FLOC

By C. J. Brockman

(*Department of Chemistry, University of Georgia, Athens, Ga.*)

There is no need to review here the enormous quantity of data on the use of copper sulfate for the control of algae in the raw water supply. The excellent report of J. K. Marquis, Superintendent of Filtration at the Spartanburg, S. C. water works, is sufficiently complete.[1]

The greater part of the discussion of the question of the use of copper sulfate has been about the quantity which may safely be used without exceeding the tolerance of the human body for copper salts. It seems that the maximum limit for safety is 0.2 p.p.m. All of this discussion has gone on for years on the assumption that all of the copper which is introduced into the raw water supply will be delivered to the ultimate user of the water, which conception, in the writer's opinion, is entirely erroneous.

During the past decade the problem of floc formation in the water works has been put on a scientific basis by the investigations of men connected with the U. S. Public Health Service and others.[2]

They have studied the conditions under which the best aluminum flocs are produced, and then extended the study to ferrous sulfate or copperas. From a study of the work on alum and iron flocs the writer is of the opinion at least some of the copper salt will be flocced out with the alum treatment and consequently be retained on the filters.

In searching the literature on the subject of such a removal of copper salts only one reference has been found in which there is any certainty indicated that the copper would be retained on the filters. The statement is, "The copper salt does not remain in solution; there are various causes for its precipitation, and it is possible that the grains of sand get coated with a layer of the precipitate."[3]

[1] Journal, Southeastern Section, A. W. W. A., page 35, 1931.

[2] E. J. Theriault, Pub. Health Reports, *38*, #5, 181, 1923. L. B. Miller, ibid., *38*, #35, 1995, 1925; *40*, #8, 351, 1925; *40*, 1413, 1925; A. M. Buswell, et. al., Illinois State Water Survey, Bul. #22, 1926.

[3] A. Kemna, Journal Gas Lighting, *96*, 813–4, 1906, from abstract in J. Soc. Chem. Ind., (London), *26*, 64, 1907.

If this be true, then the amount of copper salt can be increased up to the concentration which will kill the fish without there being any appreciable quantity of copper salt left in the treated water.

This paper is a report of a preliminary investigation only made to determine if there is any adsorption of copper salts by the aluminum floc.

Jar tests according to the method of the New York State Department of Health were made using the raw water supply of Athens, Ga. Filter alum of the Athens Water Works was dissolved in distilled water so that when 1 cc. of this solution was added to 1 quart of water the alum concentration was 0.5 grain per gallon. The copper sulfate solution was prepared in distilled water by dissolving

TABLE 1

TEST NO.	RAW WATER						COPPER IN FILTERED WATER	
	Alum solution			Copper solution			Residue	Filtrate
	cc.	*g.p.g.*	*p.p.m.*	*cc.*	*g.p.g.*	*p.p.m.*	*p.p.m.*	*p.p.m.*
1	1	0.5	8.85	5	0.029	0.5	0.5	None
2	1	0.5	8.85	4	0.023	0.4	0.4	None
3	1	0.5	8.85	3	0.017	0.3	Sample lost	
4	1	0.5	8.85	10	0.058	1.0	1.0	None
5	1	0.5	8.85	20	0.116	2.0	1.8	0.2
6	2	1.0	17.1	10	0.058	1.0	0.5	0.5
7	10	5.0	85.5	10	0.058	1.0	0.0	1.0
8	20	10.0	171.0	10	0.058	1.0	0.0	1.0
9	10	5.0	85.5	20	0.116	2.0	0.1	1.9
10	10	5.0	85.5	0.0	0.000	0.0	0.0	0.0
11	5	2.5	42.75	10.0	0.058	1.0	0.1	0.9

0.3928 g. $CuSO_4 \cdot 5H_2O$ in 1 liter, which made the copper concentration 0.1 mg. per cc. or 0.1 part per million when 1 cc. was diluted to 1 liter. In this work it will be considered that 1 quart is the equivalent of 1 liter.

The method of procedure was to add a quantity of alum solution and of copper sulfate solution to the raw water in quart jars. When the floc had settled it was filtered through a large funnel. The filtrate was evaporated in Pyrex vessel to 50 cc. and was analysed for copper by slightly acidifying with dilute sulfuric acid, and then making alkaline with ammonium hydroxide in order to precipitate the aluminum hydroxide and leave the copper salt in solution. The aluminum hydroxide was filtered, and the copper determined in the

filtrate by the ferrocyanide method after evaporating the excess of ammonia from the sample.

The floc which was filtered from the raw water was treated on the filter paper with a few cc. of warm 3 N H_2SO_4 to dissolve the acid soluble portion of the floc. This was allowed to run through the filter with wash water. This acid solution was then made alkaline with ammonia, the aluminum hydroxide filtered off, and the copper determined in the filtrate as above described. The results are given in table 1.

The first five tests show that when a small quantity of copper sulfate was added to raw water containing a small amount of alum the formation of the floc removed the greater portion of the copper salt. The last six tests in which more alum was used did not produce good flocs and the copper adsorption was not so good.

It was not convenient to determine the pH of these solutions. The raw water used had a pH of 7.0. From this preliminary work it may be safely stated that under ordinary operating conditions where a neutral water is treated with about 0.5 g.p.g. of alum and about 0.2 p.p.m. of copper sulfate there will be an almost complete removal of the copper salt in the water treatment plant.

This work is being continued in order to determine the exact concentration and pH ranges in which copper salts are removed in water treatment.

(*Presented before the Southeastern Section meeting, April 5, 1933.*)

CHEMICAL ACTION BETWEEN FILTER MEDIA AND HOT ALKALINE WATERS

By Homer G. Turner

Director of Research

AND

G. S. Scott

Assistant Director of Research

(Anthracite Institute, State College, Pa.)

It has been known for some time that hot, alkaline waters dissolve silica. In J. W. Mellor's Treatise on Inorganic Chemistry, Vol. VI, page 278, it is stated that 100 parts of water dissolve 0.01 part silica and that the solubility is increased by oxygen. It is also stated that silica is dissolved by sodium hydroxide, potassium hydroxide, hydroxides of the alkaline earths, sodium carbonate, and potassium carbonate solutions.

It has been shown[1, 2] that sodium carbonate under boiler conditions decomposes into sodium hydroxide and carbon dioxide.

Joos states[3] that sodium carbonate, or soda ash, present in boiler waters (either naturally or as the result of chemical treatment by soda ash, boiler compound, a lime soda softener) undergoes a transition under steam conditions. He found a 72 percent conversion of sodium carbonate to caustic soda at 146 pounds per square inch boiler pressure, and 82 percent conversion at 280 pounds. The conversion at 145 pounds was complete in about two hours, and was but little affected by rating.

Powell states[4] that frequently as little as 5 p.p.m. of silica has caused serious damage in certain boilers operating in excess of 400 pounds pressure. The effect of interaction between the filter medium and the water being filtered is apparently a problem of some impor-

[1] Paul, Boiler Chemistry, page 38 (Longmans, 1919).
[2] Straub and Larsen, Ind. Eng. Chem., 24: 1416, 1932.
[3] Power, November 12, 1929.
[4] S. T. Powell: Private communication.

tance and would seem to be due largely to the presence of free hydroxyl ions.

In order to obtain some quantitative data on the relative solvent effect of hot alkaline solutions on Ottawa sand, a silicious filter material and Anthrafilt, essentially a non-silicious filter medium, two series of laboratory experiments were carried out at temperatures ranging from 270°F. to 365°F. and with concentrations of NaOH solutions of 0.1 and of 1 percent. The screen size of each material was 20 x 30 U. S. mesh screen. The tests were made in a copper autoclave. Time of contact was varied from one to 48 hours. In the first series of tests a fresh sample of filter medium and a fresh quantity of NaOH solution were used for each test. In the second series of tests the same sample of filter medium was used throughout with a fresh quantity of NaOH solution for each test. In this second series the time, temperature, and concentration of NaOH solution were held constant.

A rather considerable quantity of data was naturally obtained from these tests and a very considerable amount of space would be necessary for the complete tabulations, charts, and detailed physical chemical treatment of the data. The main facts, however, may be stated briefly. As the nature of the data obtained for the two different filter media require somewhat different treatment for an understanding of the behavior of these two materials with respect to hot alkaline solutions, they are best discussed separately.

In considering first the solvent effect of the alkaline solutions upon silica sand it may be said that the chemical reaction here takes place according to the well-established physical chemical laws for heterogeneous reactions. This fact, however, is not apparent until corrections are made for changes in surface area and for the slight amount of adsorption which takes place. The data for sand may be summarized in the equations following.

The relation between reaction velocity constant, and absolute Fahrenheit temperature was found to follow the equation:

$$2.303 \log K = \frac{48100}{T} - 0.5417T + 92.28$$

The numerical value of the constant, K, of course, depends upon the units used in its calculation.

It was found that the surface area of the sand does not decrease with weight loss according to a linear relationship, as assumed by

Hixson and Crowell[5] but first increases to a maximum and then decreases gradually to zero. The empirical equation expressing this relationship for 100 cc. (162 grams) of 20 x 30 mesh Ottawa sand is:

$$O^2 = 16 + 19.75W - 0.3975W^2 + 0.001985W^3$$

where W represents the weight loss of the sand in percent and O equals the surface area in square centimeters. In this case O reaches a maximum at about 33 percent weight loss. For any other quantity or size of sand the result obtained from the above equation may be multiplied by the ratio of the volumes or weights and also by the ratio of the squares of the respective average diameters of the particles.

With values for K and O the actual concentration of dissolved silica may be calculated by means of the equation:

$$2.303 \log \frac{S}{S - C} = O.K.t$$

where t is the contact time in hours. S represents the saturated condition and is equal to 10.65 $\times$ percent NaOH (initial). When the computations are carried out the figure for C (= concentration of dissolved silica) is in grams per liter.

In one series of tests a sample of sand was subjected to the action of hot alkali solution until a total weight loss of 65 percent was shown. It was found in the case of this sample that the effective size had decreased from 0.61 to 0.42 mm. and the uniformity coefficient had changed from 1.21 to 1.31. Figures 1 and 2 of plate I show the appearance of the sand grains before and after the tests. Figure 5 shows the volume of sand remaining from an original volume of 100 cc. (white).

In the case of Anthrafilt the results are somewhat more complex. The reaction products here appear to displace the equilibrium to the left and at the same time the concentration of dissolved silica decreases exponentially to zero. It was shown from the second series of tests that ultimately 87 percent of the ash of the Anthrafilt would be removed. As the Anthrafilt contains about 8 percent ash and of this about 50 percent is silica, the total ultimate quantity of silica dissolvable is about 3.6 percent. A complete exposé of the methods for calculating concentration of dissolved silica from Anthrafilt under

[5] Ind. Eng. Chem., 23: 923, 1931.

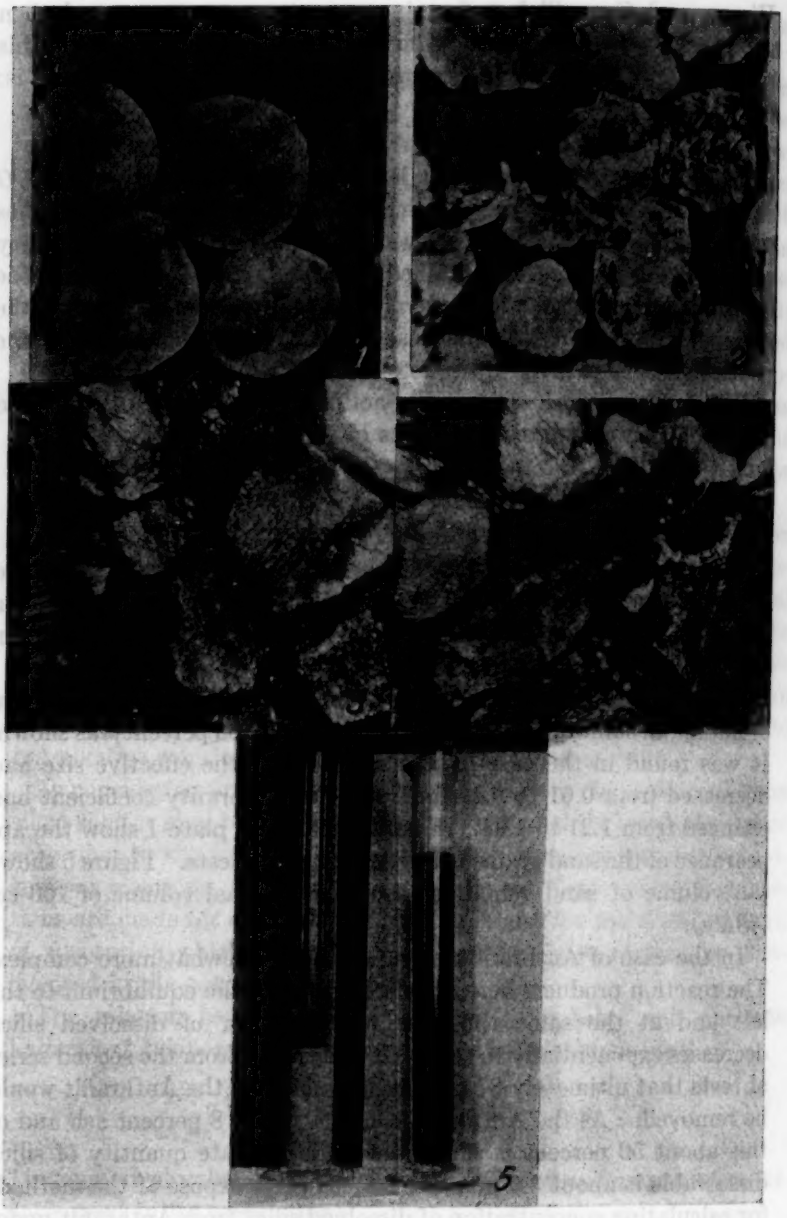

PLATE I—FIGS. 1-5

different conditions of time, temperature, alkali concentration and so forth would give the reader much more exercise in mathematical gymnastics than the result would warrant. The important point to be noted is that the solution rate from Anthrafilt is highest at the beginning and decreases exponentially to zero. This maximum beginning rate is approximately one-tenth as fast as the initial rate of solution from silica sand. Figures 3 and 4 show a sample of Anthrafilt after being subjected to the same treatment as the sand shown in figures 1 and 2. Figure 5 is from the same series of tests and shows the volumes of sand and Anthrafilt remaining after being subjected to similar treatment. The original volume was 100 cc. It is important to note that the Anthrafilt has decreased in volume only to a very slight extent and that its effective size and uniformity coefficient have not changed.

In conclusion, it might be stated that under like conditions the initial rate at which silica is dissolved from sand by NaOH solutions is about ten times the initial rate at which it is dissolved from Anthrafilt. In the case of silica sand the solution rate increases up to a maximum of about four times its initial rate before it starts to decrease, whereas in the case of Anthrafilt the solution rate immediately starts to decrease and reaches zero exponentially.

PRELIMINARY PROGRESS REPORT OF THE COMMITTEE ON "METHODS OF ANALYSIS OF WATER PURIFICATION CHEMICALS"

At the Memphis Meeting of the Association, a general agreement was voiced on the necessity of securing and bringing into line specifications and methods for the evaluation of all commercial chemicals now used in water purification. The Association, therefore, authorized the Chairman of the Water Purification Division to form a special Committee on "Methods of Analysis of Water Purification Chemicals."

The Committee was duly appointed by Mr. J. W. Ellms, Chairman of the Water Purification Division, in December, 1932.

The Committee was advised to review in detail the procedures now current in water works laboratories by means of which the quality of these chemicals is determined and to devote especial attention to methods of inspection, sampling and testing. Incidental to this, it was suggested that the Committee might properly engage itself to formulate and propose specifications for the control and purchase of these same materials. The Committee was further instructed to give no attention to those chemicals "that are not consumed or rendered inert by the work they do," with zeolites as an example.

After a brief review of the assignment, a prescribed study of some twenty-seven chemicals was contemplated. In order that the Committee might coördinate and direct its effort to the best advantage, it seemed advisable to apportion and assign a given number of these chemicals to each member for individual study and investigation. The work was accordingly subdivided among the personnel of the Committee on the following plan:

R. C. Bardwell, Supt. of Water Supply, C. & O. R. R. Co., Richmond, Va.
Barium Carbonate, Caustic Soda, Soda Ash, Sodium Aluminate, Sodium Chloride, and Tri-sodium Phosphate.

William U. Gallaher, Chemist, Water Department, Appleton, Wis.
Anhydrous Sodium Bisulfite, Calcium and Sodium Hypochlorites, Liquefied Chlorine, and Liquefied Sulphur Dioxide.

Gilbert L. Kelso, Supervising Engineers, Inc., Greensburg, Pa.
Activated Carbon, Bleaching Clays, Hydrated Lime, Quick Lime, and Sodium Iodide.

Winfield S. Mahlie, Chemist-in-Charge, Filtration Plant, Forth Worth, Texas.
Aluminum Sulphate, Bauxite, Soda Ash, and Sulphuric Acid.

August G. Nolte, Chief Chemical Engineer, Chain of Rocks Plant, St. Louis, Mo.
Ammonium Chloride, Ammonium Sulphate, Ferrous Sulphate, Ferric Sulphate, and Ferric Chloride.

George R. Spalding, Asst. Supt. of Filtration and Sanitation, Hackensack Water Co., New Milford, N. J.
Activated Carbon, Copper Sulphate, Hydrated Lime, Quick Lime, and Potassium Permanganate.

Mathew M. Braidech, Senior Chemist, (Chairman) Baldwin Filtration Plant, Cleveland, Ohio.
Activated Carbon, Aluminum Sulphate, Ammonium Hydroxide, Anhydrous Ammonia, Liquefied Sulphur Dioxide, and Fuels for Re-carbonation.

At the time of its organization, the Committee decided, for the sake of completeness, to go into its assignment rather extensively. After some earnest thought, it was deemed well worth while to include in its survey such additional supplementary data pertaining to the grades, manufacture, properties, and the uses of the chemicals, which could be brought within the compass of a suitable treatise for ready reference. It was agreed, therefore, to prepare a monograph on each chemical according to the following outline:

I. *Name:* Chemical name, formula and various commercial trade names.
II. *General considerations:*
  1. Definition—a brief description of the chemical.
  2. Manufacture—a brief statement on the method of manufacture of the chemical.
  3. Physical and chemical data—data relating to the solubility, specific gravity, latent heat of vaporization, etc.
  4. Use in water purification—a brief statement on the purpose in water treatment.
III. *Specifications:*
  1. Chemical requirements.
  2. Physical requirements.
IV. *Containers:*
  1. Packing and shipping.
V. *Weighing, inspection, sampling, retesting, rejection, etc.:*
  1. Weighing and Inspection.
  2. Method of collection of composite gross sample.
  3. Preparation of the laboratory sample.
  4. Retesting and rejection.

VI. *Methods of tests:*
1. Preliminary examination.
2. Analytical chemical determinations:
   A. Determination of chemical constituent (A):
      a. Reagents.
      b. Apparatus.
      c. Procedure.
      d. Calculations.
      e. Explanatory notes and precautions.
      f. Alternative or optional methods.
   B. Determination of chemical constituent (B): (etc.) a, b, c, d, e, and f, same as above.
3. References and bibliography.

SOURCE OF INFORMATION

In preparing the ground work of the present status of the subject matter, the personnel of the Committee aimed to coördinate the interests of both the water works operator and the manufacturers of the chemicals. Therefore, the Committee was instructed to make every effort to secure definite material from actual current practice and describe procedures which are typical of those employed in the usual commercial and industrial analysis—as having been officially recognized, or repeatedly tested with satisfactory results in the hands of different analysts. It was further requested to avoid unnecessary long and academic instructions and to endeavor to give only such concise and explicit directions in each procedure as is consistent with reasonable completeness, so that anyone familiar with analytical technique can readily follow them.

With these suggestions in mind, the Committee activity was directed along the following lines:

1. A review of the work of the previous Committees was made.
2. Contacts were established by correspondence with the principal water works laboratories, interested manufacturers, and various other authorities.
3. Co-operative relations were established with other bodies and organizations engaged in like or cognate subjects, namely:

American Railway Engineering Association,
American Society for Testing Materials,
American Chemical Society,
American Gas Association,
National Lime Association,
The Association of Official Agricultural Chemists, Inc.,
The Edison Electric Institute,
The Chlorine Institute,

The Federal Specifications Board, including,
Bureau of Supplies and Accounts of the U. S. Navy, and
Office of the Quartermaster General of the War Department.

4. By reviewing important information and usable data in standard texts and treatises, trade bulletins, original papers, and technical and scientific journals.

REVIEW OF WORK OF PREVIOUS COMMITTEES

The first definite contribution toward improving specifications and methods of chemical analysis for water purification chemicals was reported in 1925 by Committee No. 12—On Testing of Water Works Materials and Supplies. Specifications were formulated for Aluminum Sulphate, Soda Ash, Caustic Soda, Lime, Chloride of Lime, Liquefied Chlorine, Ferrous Sulphate, and Copper Sulphate; and were appended to the "Manual on Water Works Practice" published in September, 1925 (see pages 707–710). The additional material on methods of chemical analysis for Aluminum Sulphate, Bauxite, Sulphuric Acid, Soda Ash, Lime, and Chloride of Lime and Ferrous Sulphate was published in the July, 1925 issue of *The Journal* (see pages 38–45).

The 1917 Edition of Standard Methods for the Examination of Water and Sewage contained methods of analysis for Aluminum Sulphate, Lime, Ferrous Sulphate, and Soda Ash (see pages 77–82), but the editions since 1923 have included no such data.

PROGRESS OF PRESENT COMMITTEE TO-DATE

Due to the fact that a number of the committee members have been pressed by their regular duties, the Committee did not have the opportunity to do all it had set out to do. However, it is very gratifying to report that some substantial progress has been made and that preliminary drafts for the following chemicals have been drawn up:

Aluminum Sulphate.
Ammonium Hydroxide.
Ammonium Chloride.
Ammonium Sulphate.
Anhydrous Ammonia.
Bauxite.
Copper Sulphate.
Ferrous Sulphate.
Ferric Sulphate.
Ferric Chloride.
Hydrated Lime.
Quick Lime.
Liquefied Chlorine.
Liquefied Sulphur Dioxide.
Potassium Permanganate.
Powdered Activated Carbon.
Soda Ash.
Sulphuric Acid.
Fuels for Recarbonation.

These monographs are not to be considered as complete or final, for there is still a great deal of work to be done on them; much information having been available a little late will have to be included. Furthermore, there has not been sufficient time to secure the complete review and criticism of the different monographs by the committee as a whole.

RECOMMENDATIONS

No attempt is made at this time to present any definite recommendations other than those which the Committee believes will tend to facilitate the completion and the final presentation of the committee report at the next regular meeting of this division.

Your Committee, therefore, requests the following action:

1. That the present report of the Committee be accepted and approved as information.
2. That the work of the Committee be continued for the ensuing year for further study and report.
3. That a list of qualified men be designated as associates to the Committee, for the critical review of advance copies of the different monographs.
4. That in due course of time the Committee be expanded to include among its personnel, referees, to check the various recommended methods of tests; and field representatives, to promote contact and further exchange of information between the Committee and its collaborators.

In submitting this report, the members of the Committee wish to acknowledge gratefully their indebtedness to their associates for their valuable counsel and collaborative effort; without their assistance and interest it would have been impossible to have carried out so much of this work in so short a period of time.

The Committee also wishes to thank all those individual members of the Association who have so generously responded to our mimeographed circular letters. The advice and information received has been most encouraging and has helped to make our program wholly effective.

In like manner, the Committee wishes to record its appreciation to the various interested manufacturers and their representatives,

for all the many favors and specific information that has been so freely released from their files and experience.

Respectfully submitted,

The Committee on "Methods of Analysis of Water Purification Chemicals" of the Water Purification Division.

R. C. BARDWELL,
WILLIAM U. GALLAHER,
GILBERT L. KELSO,
WINFIELD S. MAHLIE,
AUGUST G. NOLTE,
GEORGE R. SPALDING,
MATHEW M. BRAIDECH
Chairman

(Presented before the Chicago Convention, June 13, 1933.)

SOCIETY AFFAIRS

THE MISSOURI VALLEY SECTION

The Nineteenth Annual Meeting of the Missouri Valley Section was held at St. Louis, Missouri, on October 26, 27, and 28, 1933. It was called to order—in the absence of the Chairman and Vice Chairman of the Section—by Director W. Scott Johnson in the Crystal Room of the Hotel Jefferson on Thursday, October 26, 1933. There were 25 people in attendance. After explaining that illness in his family prevented the attendance of Chairman Joseph S. Nelson and expressing the regret of the Section that this circumstance existed, Mr. Johnson introduced the Round Table Discussion.

Topic No. 1—"Policy in Handling Delinquent Accounts," outlined by George J. Keller, General Manager of the Iowa Water Service Co. at Iowa City, Iowa, who stated that his experience with delinquent accounts indicated that they might be divided into three classes: (a) those where there was real inability to pay, (b) those of the continual objectors, and (c) those of people who do business on other people's money. The policy of his company was to be lenient with the first class, but to enforce regulations in those instances where investigation showed clearly that inability to pay was not the real reason for the delinquent account.

J. M. McEvoy, Superintendent of Water Works at Dubuque, Iowa, stated that in his city 1200 water bills in 1932 and 1000 water bills in 1933 had been worked out on made work projects. This work was largely on city parks and playgrounds. One difficulty that had arisen was that there was a tendency for consumers purposely to let the water bill run with the idea that it could be worked out. The department does not have enough work. Recently a new policy of investigating each case has been adopted. If it is found that the consumer is not being helped by relief organizations the shut-off regulations are explained with the statement that the investigator will return in a few days. This usually brings payment, but the Department does not actually shut off the water.

William Molis, Superintendent of Water Works at Muscatine, Iowa, stated that they had laid a mile of pipe using delinquent con-

sumers for the labor and that at the present time the slate was just about wiped clean.

W. V. Weir, Superintendent of the St. Louis County Water Company, stated that his company had about 36,000 accounts. They are not in a position to make arrangements for working out delinquent bills. Their policy is to use one man as a bill collector. Thus far it appears that the collector collects just about enough to pay his own salary.

H. V. Pedersen, Superintendent of Water Works at Marshalltown, Iowa, indicated that the delinquent account situation was much the same in his city. They will not turn off water from any worthy person, but it is sometimes hard to decide what the merits of the case really are. It is his policy to call delinquents into the office and have them sign a statement to the effect that they will settle the water bill as soon as possible. During the past year the Department has provided a considerable amount of work for unemployed water consumers.

In Council Bluffs, Iowa, J. Chris Jensen, Water Works Trustee, said that their policy was to make an investigation of the situation of delinquents. They shut-off water when evidence shows that such procedure is justified but they are carrying some 1600 delinquent accounts which they feel are worthy. There is nothing to do but to let people have water when they have no means of support.

W. Scott Johnson, Sanitary Engineer of the St. Louis Health Department, brought out the point that water was essential from the health standpoint. He did not believe in shutting off water entirely, but thought that restricted service might be acceptable and adequate in providing for healthful conditions in the home.

George A. Nelson, Superintendent of Water Works in Boone, Iowa, asked how deposit accounts might be used in settling delinquent accounts. The resulting discussion was to the effect that such accounts were not particularly useful in meeting the present situation.

At this point Chairman Johnson introduced Mr. Edward E. Wall, Director of Public Utilities in St. Louis, who extended a personal welcome and then introduced the Hon. Bernard F. Dickmann, Mayor of St. Louis. Mayor Dickmann extended a most cordial welcome to the Section on behalf of the City of St. Louis.

Round Table Discussion was then resumed and Topic No. 2 "Routine Care of Filtration Plant Equipment" was introduced by John Allgeyer, Superintendent of Filtration at the St. Louis Chain of

Rocks Plant, who pointed out the necessity of regular inspection and repair of operating devices. Recording devices on the filter operating table should be checked frequently as moisture conditions effect the strings on the gauges. Mr. John C. Detweiler, Superintendent of Construction of the Metropolitan Utilities District at Omaha, stated that one man's time was entirely taken up by scheduled inspection of purification plant equipment.

Topic No. 3, "Routine Water Works Operation Records" was presented by Thomas J. Skinker, Distribution Engineer, St. Louis Water Works, who pointed out the value of having accurate records of the location of underground structures. Building lines are more satisfactory than curb lines as reference lines. Valves and hydrants should be located on large scale maps. Records are also shown on map panels. Each emergency truck carries copies of map panels for its district. Messrs. Molis and Pedersen emphasized the value of operating records.

The nominating committee, George A. Nelson and C. M. Daily, made the following nominations for officers of the Section for the ensuing year.

Chairman—August V. Graf, St. Louis, Mo.
Vice-Chairman—George J. Keller, Iowa City, Iowa
Directors—D. L. Erickson, Lincoln, Nebraska
Earnest Boyce, Lawrence, Kansas
N. T. Veatch, Jr., Kansas City, Missouri
W. W. Towne, Pierre, South Dakota
Harry Badley, Carroll, Iowa

The report was received and placed on file.

Fifty members were present when the meeting was called to order by Mr. Johnson on Thursday afternoon, October 26. The entire session was devoted to a Symposium on "The Federal Emergency Administration of Public Works—What can be done for Water Works." Various phases of the question were discussed by Col. Hugh Miller, State Engineer for Missouri; John C. Pritchard, Consulting Engineer of St. Louis, H. C. Delzell, National Recovery Committee for Water Works Construction, and Herbert Bosch, State Public Health Engineer of Missouri. The need of accelerated effort to bring forward needed projects and to get approved projects into the construction stage was emphasized. Many individual problems were brought out and methods of solving them were suggested by Col. Miller and others.

The Acting Chairman announced the appointment of the following committees:

Resolutions—J. Chris Jensen, Chairman, August Nolte, J. C. Detweiler, Otto Reynolds and Herbert Bosch.

Auditing—W. V. Weir and John Strang.

Friday morning, October 27, the meeting was called to order by Acting Chairman Johnson at 9:45 A.M. The following papers were presented.

1. "Missouri Water Supplies," Herbert Bosch, Public Health Engineer, State Board of Health, Jefferson, Mo.
2. "St. Louis County Water Co. Plant," W. V. Weir, Superintendent, St. Louis County Water Co., University City, Missouri.
3. "The Howard Bend Plant of the St. Louis Water Works," C. M. Daily, Water Commissioner, St. Louis.
4. "The Effect of Economic Conditions on Water Works," N. T. Veatch, Jr., Consulting Engineer, Black & Veatch, Kansas City, Missouri.
5. "The Marshalltown Water Department," H. V. Pedersen, General Manager, Water Works Department, Marshalltown, Iowa.

The first paper on the afternoon program "Are the Water Samples from Your Plant Truly Representative?" Jack J. Hinman, Jr., in the absence of the author was read by title. The following papers were then presented:

2. "The New Water Treatment Plant at Ottumwa, Iowa," Horace A. Brown, Superintendent of Water Works, Ottumwa, Iowa.
3. "Zeolite Water Softening by Municipalities," J. H. Murphy, The Permutit Co., St. Louis.
4. "Some Applications of Activated Carbon," John P. Harris, Industrial Chemical Sales Co., Chicago.

Following the presentation of papers on Friday afternoon came the Business Session.

Mr. H. V. Pedersen, Section Representative on the Board of Direction of the American Water Works Association, made a verbal report of his official activities during the past year. He asked for instructions in regard to his vote on the place for the next meeting of the Association. After some discussion it was voted that the preference of the members present was that the meeting be held either in Washington or Philadelphia.

The Secretary-Treasurer made the following report, which was accepted and ordered placed on file:

REPORT OF THE SECRETARY-TREASURER, MISSOURI VALLEY SECTION, A. W. W. A., OCTOBER 1932 TO OCTOBER 1933

The Secretary attended the Conference of Section Secretaries which was held in Chicago at the same time as the Annual Meeting of the American Water Works Association last June. The purpose of the meeting was to develop a program for the participation of water works men in the utilization of the provisions of the National Industrial Recovery Act. Before going to the Chicago meeting the Secretaries had been asked to obtain all possible information in regard to needed water works improvements in their districts. This information was submitted at the Conference and tabulated for the use of the authorities in Washington. A tentative program for the functioning of the Section organizations in furthering the Public Works Section of the N. R. A. was formulated. Later a Committee was appointed by the Section Chairman to carry out P. W. A. plans as they applied to water works. The progress report of this Committee has been submitted at this meeting by its Chairman, Mr. Jack J. Hinman, Jr. It is evident that a tremendous amount of work has been done by the Committee. Certainly water works men within the Missouri Valley District have been advised of the possibilities under the P. W. A. and have been offered assistance in obtaining aid for their water works improvement programs.

Membership

The membership record for the Missouri Valley Section compiled by the Secretary and submitted herewith shows that during the past year the total membership has dropped from 142 to 131, about 8 per cent. These figures are perhaps not as good as they appear, since the Secreary was recently advised by the Central Office of the A. W. W. A. that there are eighteen members of the Section who had not paid their dues for the current year. It is hoped that this number may be greatly reduced before the end of the year.

Finances

The Section has had a good year financially. In addition to receiving balances from registration fees unexpended at the Lawrence and Sioux City meetings, a ten per cent dividend, amounting to

$88.22, was paid by the Iowa City Savings Bank which closed January 10, 1933. The allotment from the parent association was $200, a reduction of $100 from the allotment of last year. The balance on hand as of October 25th was $379.94.

Respectfully submitted,

EARLE L. WATERMAN,
Secretary-Treasurer.

Membership Record

October 1932 to October 1933

STATE	NO. OF MEMBERS 1932	MEMBERS DROPPED, DECEASED, RESIGNED, TRANSFERRED	NO. OF MEMBERS TRANSFERRED TO MISSOURI VALLEY SECTION	NO. OF NEW MEMBERS	NO. OF MEMBERS 1933
Iowa	52	9	0	3	46
Missouri	58	8	2	3	55
Nebraska	9	0	0	0	9
Kansas	17	3	0	1	15
South Dakota	6	0	0	0	6
Total	142	20	2	7	131

The following report of the Resolutions Committee was presented J. C. Detweiler and unanimously adopted:

"WHEREAS, the Missouri Valley Section of the American Water Works Association in formal session at St. Louis, Missouri, on October 26, 27, and 28, has enjoyed both from a technical and social standpoint a most profitable and enjoyable meeting.

"*Therefore, Be It Resolved*, that this Association express its sincere appreciation to the Hon. Bernard F. Dickman, Mayor of the City of St. Louis, and Col. E. E. Wall, Director of Public Utilities, and other officials and employees of the City of St. Louis Water Department and St. Louis County Water Department for their splendid effort and invaluable assistance toward making this 19th Annual Meeting of the Missouri Valley Section a most successful meeting.

"That we express our thanks to those responsible for the enjoyable tours of the water works and other properties in and near the City of St. Louis, and for the delightful luncheon and entertainment so graciously provided for the members and lady guests by the Water Department of the City of St. Louis.

"That we offer our appreciation for the untiring and unceasing efforts of the officials of the Missouri Valley Section of the American Water Works Association who are largely responsible for the success of the Association and this meeting, and to those members who have so graciously assisted by presenting papers at this session.

"That the Missouri Valley Section is especially indebted to those members on National Industrial Recovery Committee of which Mr. Jack J. Hinman, Jr., is chairman and D. L. Erickson, W. W. Towne, John Pritchard, and Earnest Boyce, assisting members in their respective areas, for their untiring efforts to assist and promote Water Works participation in the P. W. A. plan, and

"*Be It Further Resolved*, that this Association go on record as expressing its most heartfelt appreciation to Mr. Tom Skinker and Mr. Earle L. Waterman, secretary of this Section, for their assistance toward the success of this meeting and for their unfailing support of the Association and the water works profession at all times.

J. CHRIS JENSEN
HERBERT BOSCH
J. C. DETWEILER

Mr. W. V. Weir, Chairman of the Auditing Committee, reported that the accounts of the Treasurer of the Section had been audited and found to be correct. The report was accepted and placed on file.

The Progress Report of the Missouri Valley Section, Sub-Committee, National Recovery Committee for Water Works Construction made by Chairman Jack J. Hinman, Jr., was discussed. It was voted that further sending out of questionnaires be discontinued. The report was received and placed on file.

Invitations to hold the next annual meeting in Kansas City, Mo.; Omaha, Nebraska and Des Moines, Iowa were presented. On motion by Mr. Frank Lawlor, seconded by Mr. Thomas Skinker, it was voted that the selection of the next meeting place be referred to the Executive Committee with power.

There was discussion of some of the salaries being paid to officers of the American Water Works Association. It was moved, seconded and carried that our representative on the Board of Direction, A. W. W. A., be instructed to suggest the advisability of investigating the possibility of a readjustment of all salaries of more than $5000 per year in the national organization.

The report of the Nominating Committee was then brought before the meeting for action. There being no further nominations presented the report of the committee was accepted and the nominees for officers were declared elected.

Upon motion, duly seconded, the Nineteenth Annual Meeting of the Missouri Section was declared adjourned.

EARLE L. WATERMAN
Secretary-Treasurer.

THE CANADIAN SECTION

List of papers read at the Ottawa Convention, March 22, 23, 24, 1933

March 22, 1933

1. "Design and Installation of Large Watermains." By C. J. DesBaillets, Chief Engineer, The Montreal Water Board, Montreal.
2. *Symposium:*
   "Methods of charging for domestic water supply." By R. L. Dobbin, General Manager, Public Utilities Commission, Peterboro.
   Flat Rate:
   G. G. Routledge, Superintendent, Water Distribution Section, Toronto.
   W. L. McFaul, City Engineer, Hamilton.
   Meter Rate:
   T. H. Hooper, Superintendent, Waterworks, Winnipeg.
   G. C. Storey, Secretary Manager, Water Commission, Windsor.
3. "Treatment of Water for Industrial Purposes. By J. O. Meadows, Sanitary Engineer, Montreal.

March 23, 1933

4. *Symposium:*
   "Operation of Water Filtration plants."
   By N. J. Howard, Director, Water Purification Plant, Toronto.
   By F. P. Adams, City Engineer, Brantford.
   By H. P. Stockwell, Chemist, Filtration Plant, Ottawa.
   By W. C. Miller, City Engineer, St. Thomas.
   By J. C. Keith, Chief Engineer, Essex Border Utilities Commission, Windsor.
   "Taste and Odor Control with Powdered Activated Carbon."
   By F. E. Stuart, Research Engineer, Water Purification Division, Industrial Chemical Sales Company, New York City.
5. "Softening Municipal Water Supplies." By W. H. Walker, Engineer, Township of Etobicoke, Ont.
6. "The Ottawa Waterworks System." By A. D. Stalker, Assistant Waterworks Engineer, Ottawa.

7. "The Hull Waterworks System." By Theo. Lanctot, City Engineer, Hull, P. Q.

March 24, 1933

8. "The Duties and Responsibilities of a Waterworks Commissioner." By Gordon S. Matthews, Chairman, Public Utilities Commission., Peterboro.
9. "The Legal Aspects of Waterworks Administration." By R. C. Harris, Commissioner of Works, Toronto.
10. "Financing Waterworks from the Commissioner's Standpoint." By G. P. Gordon, Commissioner of Finance, Ottawa.
11. "Public Health Engineering in the Province of Quebec." By T. J. Lafreniere, Sanitary Engineer, Provincial Bureau of Health, Montreal, P. Q.
12. "Construction of Intake Pipe and Junction Shaft for City of Toronto Duplicate Water Supply." By F. W. Douglas, Toronto.
13. Round Table Conference.

ABSTRACTS OF WATER WORKS LITERATURE

FRANK HANNAN

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Composition of Earth Dams. Discussion. Part 1. Eng. News-Rec., **106**: 960–966, June 11, 1931. Detailed discussions of three papers published in Eng. News-Rec., **105**: 954–65, December 18, 1931. **Further Study of Earth Dams and Better Terminology Needed.** J. ALBERT HOLMES. 960–2. There is record of impounding embankments built 4000 years ago, and embankments more than 2000 years old are still in use. Such an ancient art deserves adequate modern terminology and method of procedure in investigation. It is of paramount interest that studies of Bureau of Reclamation on "percolation through earth dams" and "mechanical composition of earth dam materials" be continued as rapidly as possible. There is need for uniform method of displaying results of analyses: a form, or chart, on which accepted classification of sizes and divisions will be shown. **Materials in Existing Earth Dams.** E. W. LANE. 962. Chart showing composition of core material in 22 existing dams and possible lower limit of size for safe core materials, given in previous article, is reproduced with one correction. **Laboratory Tests Can Never Supplant Sound Judgment.** O. N. FLOYD. 963–5. Generally, between rather wide limits, nature and grading of materials available for construction of earth dam are of less importance than knowledge of what is available and how best to handle it. Unsatisfactory condition in core can be detected definitely and immediately with 6-inch cast iron ball and round wooden pole. Laboratory analyses and tests of materials for earth dams should increase in value as they are extended and the results are tested in practice, but their limitations should not be overlooked. **Gradation of Materials in Earth Dams an Important Factor.** CHARLES H. PAUL. 965–6. Considerable leeway seems to be permissible as to size and gradation of suitable core materials. Availability of suitable coarse stable material for outer slopes is fully as important in hydraulic-fill construction. Basic theory of earth dam design should not be forgotten, namely, to have approximately impervious material in upstream section, gradually changing to more and more pervious material toward the downstream slope. Special considerations modify the requirements for upstream face, but, so far as downstream section is concerned, nothing contributes so much to safety and security as plenty of coarse, stable, free-draining material.—*R. E. Thompson.*

Composition of Earth Dams. Discussion. Part II. Eng. News-Rec., **106**: 1044–8, June 25, 1931. **Character of Available Material Fixes Core Dimensions.**

ALBERT S. CRANE. 1044–5. It is impracticable to set definite dimensions for core without knowing characteristics of borrowpit material. Cores of dams built by hydraulic process should be only wide enough to be practically impervious, and up- and down-stream portions of dam should be well consolidated and, whether self-draining or not, should have sufficient stability to retain core. **Slides During Construction Are Not Due to Core Pressure.** FRANK H. COTHRAN. 1045–7. Discussion of slippages in semi-hydraulic fill dams. Three major considerations in earth dam construction are: (1) sufficient spillway capacity to prevent overtopping; (2) after satisfactory foundation considerations, impermeability, to such a degree, at least, as will assure entire loss of head of all seepage water, so that its capacity to carry away particles is destroyed; and (3) slopes that will be stable against slippage under all conditions. Author believes that for semi-hydraulic fill dams, built of material such as prevails in Piedmont section of South Atlantic states, most constant cause of tendency to slipping is presence of water under pressure in porous zone immediately behind thin outside layer of material incapable of drainage unaided. This is true of such dams in that section as have had slides. Core pressure was in no case invovled. **Major Settlement of Dam Cores Occurs During Construction.** A. C. EATON. 1047–8. More vital elements to be doubly sure about in construction of earth dams are related matters of foundation conditions, structures adjacent to, or through, the dam, and safe provisions against floods. Completed earth dam, considered by itself, has a pretty clean record in service. Writer believes that most of settlement in sluiced core has occurred by time dam is completed and that relatively small amount of settlement following completion is in upper part, possibly in upper 30 or 40 feet.—*R. E. Thompson.*

Composition of Earth Dams. Discussion. Part III: New Data. Eng. News-Rec. **107**: 168–72, July 30, 1931. **Conklingville Dam Built by the Semi-Hydraulic Method.** EDWARD H. SARGENT. 168–170. Description of structure completed during past year on Sacandaga River by Hudson River Regulating District. Reservoir, which has capacity of 868,000 acre-feet, will be employed for flood control and for regulation of flow of Hudson River for power, navigation, and sanitation. Dam is 1100 feet long and 100 feet high. Analyses of borrowpit and core materials are shown graphically. Device developed for obtaining samples of core material is described. Measurements indicate that settlement has almost ceased. **Variations from American Practice Found in German Dams.** J. ALBERT HOLMES. 170–2. Description of Niederwartha and Friedland dams designs of which differs from American practice in more elaborate grading, arrangement, and placing of materials. The more impervious material is placed on, or near, the water face, and perviousness increases downstream to provide internal drainage. The Niederwartha is a pumped storage plant taking water from Elbe River. Reservoir has maximum depth of 108 feet and capacity of 70,000,000 cubic feet. Crest of dam is 138 feet above valley floor at center line, and 115 and 164 feet at upstream and downstream toes, respectively. Crest width is 32.8 feet and base width about 1150 feet. Friedland dam, which has maximum height of 58 feet and length of 2660 feet, is located on Alle River, in East Prussia. Reservoir has capacity of 706,000,000 cubic feet and surface area of 1.62 square miles.—*R. E. Thompson.*

Deadwood Dam Construction Work Controlled by 60-Mile Truck Haul. R. J. NEWELL. Eng. News-Rec., 107: 144, July 23, 1931. Details and dimensions of 153-foot Deadwood dam of Boise irrigation project in Idaho are given on drawing of structure. All materials had to be hauled by truck over 60 miles of forest service and construction roads.—*R. E. Thompson.*

Checking Past Population Forecasts. NATHAN B. JACOBS and ARTHUR W. SKILLING. Eng. News-Rec., 106: 854–6, May 21, 1931. Population forecasts made in past years for number of American cities, when checked against actual enumerations made in 1930, show tendency to overestimate future population growths. Errors ranged from 118 per cent in case of small community of less than 10,000 to only 3 per cent for New York City. Average error in predictions for 50 cities and towns, involving about one-sixth of population of United States, was 4.1 per cent. In general, forecasts for large cities were far more accurate than those for small municipalities. This is shown in tabulation in which cities and towns are grouped according to population. Of the 50 predictions, 41 were in excess of census figures. This seems to show that usual engineering practice is to make ample allowance for population growth, although other factors may be involved. Similar comparison made by G. C. HOUSER (American City, September, 1928, 124) showed that of 56 predictions, 43 were overestimates. In all of 50 predictions reviewed, method of forecasting was universally one depending either in part, or wholly, upon population history of particular community involved. Graph is included showing that population of United States as a whole has been one of regular growth. Steady and consistent rates of growth exhibited by large populations may be considered in connection with problems involving smaller units. Basically, forecasting for a large area affords a control to which population of its sub-areas may be adjusted. In addition, population of a city may be expressed as simple ratio of population of state, or of other large area of which city is part, and history of this relationship studied. Census of 1930 emphasizes danger of too great dependence upon past population trends in any individual community and importance of supplementing mathematical and graphical forecasts with sane judgement. Census showed that there were 20 cities with population of 25,000, or more, that had lower population in 1930 than in 1920. Departure of these cities from past growth trends points to importance in forecasting of what has been called "the imagination to grasp the significance of apparently trivial events." Periodic check-ups on forecasts are a necessity.—*R. E. Thompson.*

Filter Sand and Effective Size. WILLIAM RALPH BALDWIN-WISEMAN. Eng. News-Rec., 107: 379, September 3, 1931. Results of researches into physical properties of filter sands and problems of interstitial flow were published in two papers, "Statistical and Experimental Data on Filtration" and "The Flow of Underground Water" (Min. Proc. Inst. C. E., 181: 15, 1910, and 165: 309, 1906). When sand bed is fully charged with water, flow takes place through irregular interstitial tubes, cross-section of which is mainly dependent on size and uniformity of particles, although it may be modified from point to point by packing and heterogeneity of the particles. Rate of flow is dependent on available pressure, length of soil tube, amount and nature of material dissolved in the

water (since this affects surface tension), and amount of air carried into pores by the water and liberated there. Although the sizes of sand grains determine dimensions of interstitial tubes to considerable extent and therefore have controlling influence on rate of flow, rate may be greatly modified by resistance that filament of water encounters in its passage through tube; this resistance will vary with angularity and roughness of material. With extremely angular rough-surfaced material of fluviatile origin, there would be more abrupt changes of section and smaller rate of flow than in interstitial tube formed by rounded polished spherical grains of æolian origin. As a readily workable formula could not be evolved depending on fineness and physical condition as revealed by microscope, and as interstitial flow is dependent among other things on behaviour of film of water enveloping the grains, it seemed that workable formula might be evolved by considering amount of adherent water that mass of sand retained after it had parted with its drainage water, weight of this adherent water being expressed in terms of an ideal film enveloping each grain. This ideal film of uniform thickness may be more of a conception than an actuality, since its thickness undoubtedly varies considerably, being reduced or increased at points of contact; but it is an appropriate conception, since excepting the straining action at or near the surface of a filter bed, filtration is largely dependent on chemical or physical instability of matter in solution or in suspension, in films of water spread out over surfaces or flowing in tenuous filaments through interstitial tubes of constantly varying cross-section. Many tests have shown fairly close agreement between thickness-of-film curve for number of graded sands and sands from filter beds of various British water works and rate-of-discharge curve for same sands, except for coarsest, where conditions of interstitial flow were hardly tenable. Although thickness of ideal film varied in general with diameter of sand grains, it did not vary directly with porosity, for, in case of sands collected from 23 different plants, extreme porosity ranged from 37.2 to 60.3 percent of total volume of sand, or from 1 to 1.62 (Cardiff, South Wales, and St. Andrews, Scotland), while extreme thickness of ideal film ranged from 1 to 5.97 (0.00159 to 0.00949 inch, Exmouth, South Devon, and Barnstaple, North Devon, respectively). In other cases, porosities differed by very small amounts (0.7 to 0.4 percent), while variation in thickness of film was 2.3 times greater. Formula as finally evolved is given in first-mentioned paper above. Subsequent work has indicated no needed revisions. Author believes that quality of any required sand may be specified by approximations, within certain limits, of: (1) aggregate surface of grains per unit volume; (2) percentage porosity; and (3) retentiveness of surface of grains, expressed in terms of thickness of ideal film. Procedure was described in paper for determining these values, which, while possibly somewhat tedious, leaves little to chance.—*R. E. Thompson.*

Workmen Break European Tunneling Record. Eng. News-Rec., 107: 225, August 6, 1931. Sixty men employed on Manchester water works project at Hawkeswater have in 5½-day week broken European tunneling record. Working continuously in gangs of 20, they accomplished the following: advanced the tunnel 180 feet, thereby breaking previous record of 163 feet created last year on Halkyn tunnel, North Wales; removed more than 1000 tons of solid rock

from aperture about 7 feet wide and 7 feet high; fired 20 rounds of explosives, by which they advanced at rate of 8 feet per round.—*R. E. Thompson.*

Swiss Methods of Avoiding Silt Deposits in Reservoirs. OREN REED. Eng. News-Rec., 107: 289–90, August 20, 1931. It is general practice in Switzerland and in Alpine portions of Germany and Italy to protect unstable banks of streams with carefully built masonry walls. In some cases stream bottom is paved with masonry and most of fall concentrated in regular steps. At Amsteg project of Swiss Federal Railways on Reuss River, a flashy mountain stream whose flow varies from 70 to 14,000 second-feet, streamflow up to 7800 second-feet may be diverted around the pond through 1000-foot tunnel. Diversion dam is an arch of cut-stone masonry with height of 105 feet, forming reservoir of 160-acre-foot capacity. Massive cyclopean masonry weir with rounded crest 140 feet long diverts flow into tunnel, which has clear cross-section of 225 square feet, enlarging to inlet area of 710 square feet. During flood periods, surface third of flow, carrying only silt and fine sand, passes through pond, while remainder, heavy in débris, is bypassed. Estimated quantity of débris carried through tunnel is in excess of 130,000 cubic yards per year (concentrated in about 3 months). Velocity at maximum flow is nearly 50 feet per second. The side walls of tunnel are of concrete, or masonry, arch roof of stone masonry, and floor is faced with granite blocks, 20 inches thick, set on 12-inch concrete base. Measurements made after 6 years' service showed that average erosion of granite floor in straight sections of tunnel was 0.16 inch per year. Silt deposit in reservoir was insignificant after 3 years' operation. On the Waeggital project, silt problem at Rempen equalizing and diversion reservoir was solved by study of reservoir location with respect to débris carried by two streams. Dam was located immediately above the junction of the Aa River and Trebsen Brook, a typical mountain torrent carrying a heavy débris load, which is diverted into reservoir after desiltation.—*R. E. Thompson.*

Laying Cast Iron Pipe. Eng. News-Rec., 107: 197, July 30, 1931. Contract unit prices given for laying of 8 miles of 10- and 12-inch cast iron pipe in Canajoharie, N. J. Contract was awarded for $25,890.—*R. E. Thompson.*

Costs of Municipal and Waterworks Construction, Birmingham, Alabama. Eng. News-Rec., 107: 279, August 13, 1931. Cost data given for laying of cast iron mains in 1929, 1930, and 1931.—*R. E. Thompson.*

Pipe Laying Costs in Duluth, Minnesota. Eng. News-Rec., 107: 279, August 13, 1931. Cost data for mains laid in 1929, 1930, and 1931 given briefly.—*R. E. Thompson.*

Experience in Cleaning Irrigation Ditches by Machine. GEORGE EBNER. Eng. News-Rec., 107: 172, July 30, 1931. Brief data given regarding experience in cleaning 460 miles of canals included in Valier irrigation projects in Montana. Cost of one-way cleaning per mile during past 3 years ranged from $92 to $95 per mile; about 6 cents per yard excavated. Since machine was

purchased in 1928, 109 to 123 miles of canal have been cleaned annually.—*R. E. Thompson.*

Old Irrigation Canal Replaced by Precast Concrete Pipe. H. H. KIDDER. Eng. News-Rec., 107: 222–3, August 6, 1931. Irrigation pipe line of 72-inch pre-cast reinforced-concrete pipe, 11,750 feet long, replacing 18,550 feet of canal, was recently completed by Hidalgo County Water Improvement District No. 2 at San Juan, Tex. In addition to above, project includes 6¾ miles of 60-inch pipe and 3,250,000 square feet of 2-inch reinforced-concrete canal lining. Pipes were cast along line of use in steel forms. Specially constructed portable plant placed the concrete in forms, where it was tamped with pneumatic vibrators. One ring of steel-wire fabric was employed, reinforcing pipe for 15-foot working head. Pipes were cast in 6-foot lengths, with wall thickness of 6 inches.—*R. E. Thompson.*

Concrete Lining for Irrigation Canals. CLYDE L. HUFF. Eng. News-Rec., 107: 270, August 13, 1931. Brief outline of procedure employed in lining irrigation canals of Mercedes district with gunite. Some 85 miles of canal have been lined and plans are underway for lining additional 100 miles. Very marked fall in ground water level followed lining of canals.—*R. E. Thompson.*

Cellular Dams Patented in 1912. N. KELEN. Eng. News-Rec., 107: 223–4, August 6, 1931. It is pointed out that dam of character proposed by C. E. GRUNSKY was patented in 1912 by firm Brüder Redlich und Berger, Vienna. The publication "Der Standsichere Mauerdamm" contains a number of similar proposals, one of which is outlined. These have never been tried in practice owing to fact that savings in concrete have been exceeded by increased cost of forms and more careful workmanship required.—*R. E. Thompson.*

Grouting Cracks Restores 30-Year-Old Dam on Merced River. HAROLD K. FOX. Eng. News-Rec., 107: 178–80, July 30, 1931. Description of repair of badly cracked and porous portions of old gravity concrete dam on Merced River, purchased by San Joaquin Light and Power Corporation in 1910. Grouting proved effective in restoring condition of structure and improving much of original concrete work. Total of 3722 sacks of cement was used in grouting 5000 cubic yards of concrete in dam.—*R. E. Thompson.*

Segregated Concrete Removed in Repairing Old Multiple Arch. Eng. News-Rec., 107: 180–1, July 30, 1931. Brief illustrated description of twenty-year-old Bear Valley multiple arch dam near Redlands, California. Repair work consisted of removing segregated concrete discovered in 3 of arches and replacement with gunite. All evidence of leakage was effectively eliminated.—*R. E. Thompson.*

Cle Elum Dam in Washington State. Eng. News-Rec., 107: 354–5, August 27, 1931. Unit prices given from three lowest tenders received for construction of Cle Elum reservoir for Bureau of Reclamation. Dam will be sprinkled and rolled earth and gravel fill, totaling 1,235,000 cubic yards. Object is to provide

additional storage for irrigating Yakima project. Outlet tunnel, through right abutment, is 14 feet in diameter inside concrete lining and 1800 feet long. Contract price is $1,603,134.—*R. E. Thompson.*

Big Tujunga Arch Dam 240 Feet High Added to Los Angeles Flood Control System. E. C. EATON. Eng. News-Rec., 107: 217–8, August 6, 1931. Completion of Big Tujunga Dam No. 1 provides initial unit in flood control plan of Los Angeles County Flood Control District to control runoff from about 100 square miles of watershed to allow complete absorption in spreading grounds for replenishment of underground storage basins. Structure is a variable-radius type, concrete arch dam, 240 feet high, with gravity abutments, providing 7500 acre-feet of regulating capacity. Completion of other three dams will provide total capacity of 47,500 acre-feet, which will be sufficient to regulate flow on to spreading grounds that will have absorption capacity of 3000 acre-feet per day. Underground storage reservoir to be used in conjunction with these regulators has present capacity of in excess of 220,000 acre-feet.—*R. E. Thompson.*

Cellular Corewall Used in Silvan Dam, Australia. IAN M. SUTHERLAND. Eng. News-Rec., 107: 377–8, September 3, 1931. Brief description of design of Silvan dam of Melbourne water supply system, now approaching completion. Dam, which consists of carefully compacted earth-fill and cellular concrete corewall, will be 140 feet high above lowest part of embankment and 2100 feet long. Reservoir capacity will be 8850 million gallons. Shafts constructed in corewall are closed at top with removable concrete covers and bottom ends are connected to drainage gallery which drains into 14-foot concrete conduit discharging at downstream toe of dam.—*R. E. Thompson.*

Public Works in Indo-China. HAROLD E. BABBITT. Eng. News-Rec., 107: 253–7, August 13, 1931. Illustrated description of public works in Indo-China, including those for irrigation and flood control. Public Works Department is responsible for water supply and sewerage of all cities. Practically all large cities have public water supplies, but little progress is being made in installation of sewerage facilities. Largest municipal water suplpy is that of twin cities of Saigon and Cholon, with combined population of 370,000. Wells, which have capacity of 2200 gallons per minute, are inadequate and extensions are under consideration.—*R. E. Thompson.*

Water Purification in Southern California. CHESTER A. SMITH. Western Construction News, 6: 16, 443, August 25, 1931. A general discussion of the physical, chemical, and bacteriological qualities of water for domestic purposes with particular reference to conditions in California. Under the subject of California Water Supply Conditions, turbidity, color, odors and tastes, and undesirable mineral contents, are discussed. There is a list of California water treatment plants, a description of the Los Angeles chlorine treatment plants and ammonia-chlorine treatment plant, also the El Centro, Beverly Hills and Wilmington Filtration plants.—*A. W. Blohm (Courtesy U. S. P. H. Eng. Abstracts).*

New Water Laws in the Making. W. L. STEVENSON and CHARLES E. RYDER. Civil Engineering, 1: 11, 991, August, 1931. This article sets down the principles established by the U. S. Supreme Court in the Connecticut and Delaware River Cases and explains the conditions under which water may be taken from interstate streams. Following are the guiding principles for use of interstate waters: (1) The doctrine of equitable apportionment controls the division and use of interstate waters; (2) Priority of appropriation creates no superiority of right in interstate waters; (3) The highest use of interstate waters is for drinking and other domestic purposes, (4) Injunctive relief will be granted only upon proof of present and substanial damage; (5) Diversion will be allowed from one watershed to another; (6) States may select sources of water supply provided no substantial damage is done to sister riparian states; (7) Release of compensation water depends upon downstream river conditions and needs; (8) Judicial allowance of diversion affecting navigation or navigable capacity is conditioned upon Federal approval. The findings summarized are: "the Supreme Court of the United States has declared that the division and use of interstate waters is not governed by the local law of the litigant States but is controlled by interstate common law, a guiding principle of which is equitable apportionment. Under such an apportionment, each state is entitled to its fair share; and priority of appropriation confers no superiority of right. Furthermore, the diversion of interstate waters, even to another watershed, will be permitted in the absence of proof of substantial damage resulting thereform, but subject always to the approval of Federal authorities respecting navigation. The selection of interstate waters as a source of supply is primarily a matter of state sovereignty, providing sister states do not thereby suffer serious injury. As an incident to such a selection, the Court may precribe as a condition that compensation water be released from the impounding reservoirs." There are two maps showing (1) Proposed interstate water diversion for Boston, Mass., (Connecticut River watershed); (2) Proposed interstate water diversion for New York City (Delaware River watershed).—*A. W. Blohm (Courtesy U. S. P. H. Eng. Abstracts).*

Oregon Highways Have "Fountain Service." FLORA E. BRECK. Good Health, 66: 6, 18, June, 1931. Drinking fountains are constructed at various points along the highway where springs are available. Water is tested periodically by the State Board of Health. The cost of these drinking fountains range from $300.00 to $1000.00 a piece.—*A. W. Blohm (Courtesy U. S. P. H. Eng. Abstracts).*

Chemical Analyses of Texas Well Waters. CHESTER COHEN. Texas State Department of Health, August 1, 1931. A forty-five page booklet giving the compilation of about 1,200 chemical analyses of the well waters in about 400 Texas cities.—*A. W. Blohm (Courtesy U. S. P. H. Eng. Abstracts).*

Swimming Pools, Simple and Satisfactory Treatment. E. L. RUFFNER. The Military surgeon, 69: 3, 306, September, 1931. During the summer of 1930, the swimming pools at The Cavalry School, Fort Riley, Kansas, were drained every fourth day and were cleaned with a hose and stiff broom. The walls were

scrubbed with a solution of copper sulphate and after cleaning the pools were allowed to sun from morning until nearly noon. Chlorinated lime was added to each pool daily and in addition, the water was treated with sodium carbonate, commercially prepared as Purite. Satisfactory bacteriological results were thus obtained at a cost of about $1.50 per day for three pools having a total capacity of 760,000 gallons. *A. W. Blohm (Courtesy U. S. P. H. Eng. Abstracts).*

Determination of Active Chlorine in Water Treated with Chloramine. RICHARD SCHMIDT. Gesundheits-Ingenieur, 55: 6, 66, February, 1932. When titration with 0.01 N sodium thiosulphate solution is used for this determination, too high values will be obtained if acid is added, because even a small addition of acid will liberate the total chlorine reserve. Thus the determination will include not only the chlorine actually free at the time and effective for sterilization, but also that which, in un-acidified water, will only later on become active, as it gradually splits off from the chloramine. The instantaneous disinfecting value is obtained by titration of the un-acidified sample after addition of potassium iodide. Distinction is to be made between chlorine actually free and the potential free chlorine which is liberated by acid.—*Manz.*

The Significance of Ammonia for the Chlorine-Binding Power of Water. M. L. KOSCHKIN. Zeitschrift für Hygiene und Infektions-Krankheiten, 114: 3, 413, November, 1932. In the determination of chlorine-binding power by the cold process, lower values are obtained after pre-ammoniation. Following is the procedure recommended for this determination. To 1 litre of water add first with constant stirring the necessary quantity of ammonia solution and and then, after 10 seconds, the chlorine solution; leave it to stand for 10 minutes in the dark and then add 10 cc. 10 percent potassium iodide solution and 10 cc. 10 percent hydrochloric acid and titrate the iodine set free with 0.01 *N* sodium thiosulphate. Chlorine addition, following same procedure, is repeated, until residual chlorine content of 0.6 to 0.7 p.p.m. is attained. According to this method, addition of ammonia in the proportion of 1:8 to the chlorine results in considerable reduction of chlorine-binding power, while further addition of ammonia produces only slight additional effect. Chlorine-binding power could be depressed in presence of organic matter of vegetable origin, to from one-half to one-third of its original value; but, in presence of organic matter of animal origin, only to 0.3 p.p.m.—*Manz.*

On Oligodynamics. F. HODER. Münchener Medizin. Wochenschrift, 79: 46, 1828, 1932. Water distilled in metal apparatus and tap water exhibit the oligodynamic phenomenon. Only in water distilled in glass apparatus, do incubated bacteria survive, even for long periods, without perceptible reduction. The oligodynamic action does not manifest itself by total destruction of germ life, but by an inhibiting effect. After standing for some time, bacterial growth reasserted itself, both in tap water and in water distilled in copper apparatus, when planted on agar, even though to considerably less extent than originally. Commercial distilled water and that distilled in copper apparatus contain traces of copper. Sodium chloride also exerts on germ life a deleterious

effect, which is greater, the more impure the salt is. For physiological work, only water distilled in glass apparatus should be used and only pure sodium chloride.—*Manz.*

The Estimation of Residual Oxygen in De-aërated Sulfite-Containing Feed Water by Means of a New Simple Apparatus. W. WESLY. Zeitschrift für analytische Chemie, 90: 7–8, 246, 1932. In de-aëration of softened feed-water by addition of sulphur dioxide, total removal of oxygen is not obtained; there remains a small quantity, which is less, the purer and more saltless the water, and the higher the temperature. In the oxygen determination, the sulfite content does not interfere with absorption of oxygen by the manganous hydroxide, but does interfere after acidifying, by reducing free iodine. Therefore, instead of the ordinary oxygen bottle a special glass vessel is used, which is fitted with sintered glass filter-plate and stop-cock, by means of which, after absorption of the oxygen, the sulfite-containing water is sucked off under an atmosphere of nitrogen. To accelerate this process, only 1 cc. of 10 percent manganous chloride solution is used, which is sufficient for the small oxygen content. In order to avoid errors due to rust particles from pipe lines, the water is filtered beforehand through glass filters and the manganese precipitate dissolved in phosphoric acid containing potassium iodide.—*Manz.*

Water Turbidity and Turbidity Measurements. ALFRED DRENNIG. Zeitschrift d. oest. Vereins d. Gas- und Wasserfachmönner, 1932; 9 1933. Part of the water requirement of Vienna, Austria, is supplied through the so-called High source conduit, the water of which developes turbidity after heavy rainfall and is thereupon excluded from distribution system. Control has up to now been based upon turbidity measurements obtained by observation of specimens of printing type. To eliminate error and delay inherent in this method, an automatic turbidity meter has been constructed. Light from standard source located at one end of circulating column of water under test undergoes partial extinction before falling upon photo-electric cell at opposite end. Current from photo-electric cell causes a condenser to become charged which automatically discharges at a given p.d., and is then recharged. The fluctuations of the light stream and therefore of the electron stream thereby generated, are a measurement of the turbidity. Measurements are made with the light-mekapion, an instrument also used for Roentgen measurements. Time required to charge the condenser is a measure of the turbidity and is recorded upon a revolving drum. When a certain turbidity is reached, an alarm is automatically set off. Gate-valves can also be set to close automatically.—*Manz.*

Importance of the Lysin (Coliphage) Test for Appraisement Hygienically of Water. K. VON VAGEDES. Zentralblatt für Bakt. Parasitenkunde und Infektionskrankheiten, I, 126: 3–4, 287, November, 1932. Cultures of Bacteria coli as proposed by NYBERG, for extraction of bacteriophages, represent a considerable step in advance for lysin test. It is advisable to employ colon strains sensitive to lysin and to control the dilution in broth by dropping upon an endo-agar plate. Instructions are given for testing water samples for coliphages. Positive reaction for coli-lysin were given by 19 out of 122 drinking water sam-

ples, by 86 out of 120 surface water samples, and by 41 out of 58 sewage-polluted samples. The examination for coliphages, for which non-sterile samples and samples even one week old are still suitable, is of decided value for judging drinking water. For judging the degree of purification of sewage-contaminated water, the test is worthless.—*Manz.*

Toxicological and Sanitary Considerations Regarding the Continuous Resorption over Extended Periods of Minute Quantities of Copper into the Human Organism. SPITTA. Reichsgesundheitsblatt, 1932: 862. As human food is prepared, or stored, in vessels of copper, and copper salts are employed in the preparation of preserved and canned goods, the quantity of copper already contained in the food will thus be increased by 4 or 5 mgms., according to LEHMANN, even by from 10 to 20 mgms. per capita daily. Part of this copper remains in the body and, according to recent observations, may possibly be not without influence in originating liver ailments. Not all, however, of this copper is continuously incorporated with the body, whereas, with the use of cupriferous drinking water, a permanent resorption takes place. A daily ingestion of 2 litres of drinking and cooking water with 2 p.p.m. copper, would mean a daily addition of 4 mgms. copper throughout life to the body, a quantity which equals from 20 to 100 percent of the quantity of copper normally contained in food. It has not been proven that the permanent addition of this quantity of copper is capable of exerting any harmful effect upon the organism: nor is it even probable; so that there is no reason generally to condemn copper water mains. The possibility that the taste of drinking water from copper pipe may be unfavorably affected, involves some hygienic risk. Positive protection does not seem to result from coatings formed on copper. Use of copper in distribution system should, therefore be limited to locations where hygienic objections lose their force, while economical and technical reasons render it advisable. Even if we are compelled to ingest copper with our food, we are not as yet constrained to do so with our drinking water, because there are other constructional materials which either are hygienically unobjectionable, or which can be rendered so by treatment of the drinking water.—*Manz.*

Appropriating Private Property. LEO T. PARKER. Water Works Engineering, 86: 12, 593, June 14, 1933. Water, diverted from natural stream into reservoir and distribution system, takes on character of personal property, ownership of which rests in appropriator. Owner of private property, who sues to recover damages for unauthorized use or condemnation of his property, cannot base suit on speculative damages. Measure of damages for permanent injury is depreciation in value brought about by city's construction of improvements. Amount of depreciation is ascertained by taking difference between value of land immediately before construction of improvement and its value immediately after completion thereof. An important point of law with respect to damages allowable for appropriation of private property for public purposes, is that amount of damages is difference between respective actual values of property before and after appropriation was made. In other words, various items cannot be considered separately. Jury may listen to testimony of witnesses, with respect to valuation of condemned or appropriated property, but

is not obligated to make the award strictly in accordance with such testimony, even although expert. Amount of damages which shall be awarded to owner of property for use of strip of land, for installation of water main, depends entirely upon depreciation of property as result of installation. Where current or flow of stream is obstructed or diverted from its natural course, and as a result thereof adjoining property is flooded, owner of flooded property is entitled to sue and recover damages based upon condemnation or appropriation proceedings. In all litigation involving condemnation of real property, the important consideration in entitling to damages is direct physical disturbance of a right, either public or private, enjoyed by property owner in connection with his property. Moreover, if by reason of such disturbance he has sustained a special damage with respect to his property, in excess of general damages, he is entitled to recover it. But loss of water rentals is not considered loss of property. Penalty clause in contract is invalid, unless it can be shown that amount specified is liquidated damages estimated equivalent to loss which will be sustained by one party in the event that the other party breaches contract. In construing written contracts, regard must be had to the situation of parties, to subject-matter of the agreement, and to object which parties had in view at time contract was signed. Also, to the further rule that intention of parties must be gathered from language used, and that this language, in case of doubt, must be taken most strongly against either grantor or grantee, if he wrote the contract.—*Lewis V. Carpenter.*

Injuries to the Pedestrian. LEO T. PARKER. Water Works Engineering, 86: 14, 681, July 12, 1933. Municipality is liable in damages for injury sustained by pedestrian as result of negligence of muncipal employees in maintaining water works accessories, such as water meters, in reasonably safe condition; but not on mere proof that city officials might have exercised great care and thereby prevented the injury. Courts frequently hold that person in position of sudden peril is not, as a matter of law, guilty of contributory negligence in failing to use sound judgment while attempting to escape impending danger, provided that he has gotten into the danger without negligence or fault of his own. Pedestrian injured on city streets as a result of his own negligence is not entitled to recover damages from city. An important point of law involving injuries caused by defective streets or appliances therein resides in fact that street repairs are ministerial functions for which municipality is liable, where it is shown that defect previously existed and that by application of ordinary care such defect should have been discovered and repaired by city officials. Municipality is not liable in damages for injury resulting from accident which would under ordinary circumstances be guarded against by average prudent and reasonably careful person, notwithstanding fact that city is operating water plant for profit. Person who sues municipality or water company for damages resulting from an injury is bound to prove not only that municipal employees produced the thing which caused the injury, but also, that injury directly resulted from negligence of municipal employee. An employee or pedestrian is entitled to recover damages in consideration of actual injuries sustained. Employer is not liable, under Workmen's Compensation Act, to make compensation for injury to employee which was the result of horse-play

or sky-larking, so called, whether injured or deceased party instigated the occurrence or took no part in it; for, while an accident, happening in such circumstances, may arise in the course of it, it cannot be said to arise out of the employment.—*Lewis V. Carpenter.*

Taste and Odors in Water. WILLIAM U. GALLAHER. Water Works Engineering, **86**: 17, 820, August 23, 1933. There are only four tastes; sweet, salt, sour, and bitter. All other tastes are either combinations of these, or purely smell sensations. Aëration will remove inorganic gases, especially carbon dioxide and hydrogen sulfide, and some of the more volatile oils. Ammoniation prevents chlorinous tastes and odors and the formation of chlorophenols. Superchlorination will help when taste and odor producing compounds can be oxidized by large excess of chlorine to less objectionable compounds. Activated carbons remove objectionable taste and odor producing compounds from solution by absorption. They remove most tastes and odors.—*Lewis V. Carpenter.*

Mountain Waters by Gravity. JAMES P. WELLS. Water Works Engineering, **86**: 13, 630, June 28, 1933. Ticonderoga draws its water supply from Goose Neck Lake. Lake was tapped by rock cut, water being delivered by gravity through 5 miles of 14-inch pipe and 2 miles of 10-inch pipe into 1,000,000-gallon concrete-lined reservoir located at city. Total cost of project was $195,000. System supplies 1,200,000 gallons per day. Keeseville, N. Y., supply, from Butternut Lake, is treated in filtration plant and conducted to city through 5 miles of 10-inch pipe. Project supplies 400,000 gallons per day and cost $100,000. Whitehall supply from Pine Lake is supplemented by water diverted from Pike Creek through 1¼ miles of 16-inch pipe. Due to drop of 400 to 500 feet, 10-inch pipe was sufficiently large to deliver 3,000,000 gallons per day through 3 miles of pipe into 1,000,000-gallon reservoir at city, from which it enters mains. Cost of project was $325,000.—*Lewis V. Carpenter.*

State Holding-Operating Units. V. BERNARD SIEMS. Water Works Engineering, **86**: 12, 590, June 14, 1933. Large holding companies have made possible public services in towns too small to develop their own. By consolidating several utilities, holding companies are able to employ expert engineers and standardize design and methods of operation. They are able to attract ablest of officials and operators to the public service. Danger of abuses, admittedly grave, is believed to be eliminated by proper state control. Final stage would be organization of one operating company in each state, composed of many individual units.—*Lewis V. Carpenter.*

Biological Problems in Relation to Water Storage. W. RUSHTON. Water and Water Engineering, **34**: 411, 665–674, Special Winter Number, 1932. In natural and artificial lakes, plankton flora follows fairly regular seasonal sequence, coinciding largely with seasonal temperature changes. Storage reservoirs generally show predominance of diatoms, such as *Asterionella* and *Synedra*, accompanied by protozoa and sometimes by *Cyclops* and *Daphnia* in late spring; green algae such as *Ankistrodesmus* are prolific between June

and August, while *Myxophyceae*, such as *Anabena*, *Aphanizomenon*, and *Oscillatoria*, appear from late July up to peak in October or November, followed again by diatoms and protozoa. Good aëration and circulation in service reservoirs check excessive algal growths, and use of algicides can be reduced to minimum, provided constant supervision is exercised over storage areas; algicides should only be used where algae are most concentrated, rather than throughout reservoirs.—*W. G. Carey.*

Research in Biology in Relation to Water Supplies. J. T. SAUNDERS. Water and Water Engineering, 34: 411, 600–602, December 20, 1932. Description of Freshwater Biological Association laboratory at Wray Castle, Lake Windermere. One purpose of investigation is establishment of biological index of purity in fresh waters, to be used in determining character, purity, and potability. Using few well chosen organisms as indicators, biological examination of reservoir water may be more rapid than chemical analysis. Study of bacterial decomposition of organic matter is important. It is suggested that water movements, determined by weather, may cause accumulation of mineral salts favorable to plant growth and so lead to appearance of certain organisms in overwhelming numbers in lakes and reservoirs. It is possible that in reservoirs production of organisms may be controlled by adjustment of inflow and outflow. Water movements in Lake Windermere are being investigated by temperature measurements.—*W. G. Carey.*

Some Important Biological Factors of River Waters and Their Bearing on Drinking Water Problems. W. RUSHTON. Water and Water Engineering, 34: 411, 588–589, December 20, 1932. Effects on stream life of over-chlorination of sewage effluents, of undestroyed organic matter remaining when free chlorine has disappeared, and of directly toxic trade effluents are discussed. Studies of bacterial pollution of rivers has shown that disease-producing bacteria disappear more rapidly than *B. coli*, and that death of organisms depends on pH, temperature, oxygen concentration, plankton, and original concentration of organisms. Biochemical oxygen demand proceeds in two stages, oxidation and then nitrification. Existence of healthy fish life is good indication of river purity and knowledge of living contents should be obtained in addition to chemical and bacteriological tests for water supply.—*W. G. Carey.*

Biological Balance in Fresh Water. Water and Water Engineering, 34: 409, 479–480, October 20, 1932. Fresh water organisms are extremely sensitive to small changes in conditions; complete change of algal flora occurs if one part of nitrate nitrogen is added to 10 million parts of water, or one part per 100 million of phosphate phosphorus; the algal flora thus affords a good test of water quality. Relationships of macro- and micro-flora to the fauna have been studied, especially to Trichoptera, Ephemeridae, Mollusca, and Gammarus; and methods for control of certain forms of life were studied experimentally. Organic effluents cause de-oxygenation, either directly, or after deposition as silt; they increase fertility of river bed, and bring in nutrient material favorable for development of sewage fungi and algae. Method for using *Polytoma uvella* to indicate oxygen deficiency in water samples is described.—*W. G. Carey.*

Wolverhampton Corporation Water Supply. The New Dimmingsdale Water Works. Water and Water Engineering, **34**: 410, 529–537, November 21, 1932. Three water works provide Wolverhampton with water. At Cosford, water is pumped from river, filtered through rapid filters, chlorinated, mixed with water from two wells, and pumped to storage reservoirs where supply from two further wells is added. Detailed description is given of new works supplying 3 million gallons per day from two boreholes. After passing through settling tanks to remove sand, water is pumped to service reservoirs, or direct into mains.—*W. G. Carey.*

Experimental Methods for the Study of Corrosion. J. C. HUDSON. Chemistry and Industry, **52**: 12, 69T–76T, March 24, 1933. Description of most important experimental methods used in study of corrosion. Laboratory methods include (1) visual inspection, (2) oxygen absorption, (3) gain in weight, (4) potential measurements, and (5) accelerated tests; field tests include (6) loss in weight, (7) gain in weight, (8) decrease in mechanical properties, and (9) increase in electrical resistance.—*W. G. Carey.*

The Rôle of Sodium Aluminate in Accelerating the Separation of Solid Phases during Water Softening Operation. L. M. CLARK and L. S. PRICE. Chemistry and Industry, **52**: 6, 35T–44T, February 10, 1933. Reactions occurring during lime-soda water softening and separation of solid phases from solutions of calcium and magnesium salts of concentrations dealt with in water softening practice are discussed. Calcium carbonate and magnesium hydroxide precipitates formed in water softening are positively charged relative to medium: differences in their behavior are ascribed to hydration of magnesium hydroxide as compared with anhydrous nature of calcium carbonate. Sodium aluminate in dilute solution (3 parts per 100,000) consists of aluminium hydroxide, partly in collodial dispersion and partly in sodium hydroxide solution, colloidal hydroxide being negatively charged relative to medium. Sodium aluminate affects rate of removal of magnesium hydroxide only, and plays no part in accelerating precipitation of calcium carbonate. This effect is ascribed to coagulation of colloidal magnesium hydroxide and not to formation of insoluble magnesium aluminate. In small scale experiments, best results are obtained by gently agitating mixture with sodium aluminate after addition of lime and soda. Solubilities and optical properties of calcium and magnesium aluminates have been measured, all work being carried out at 30°C.—*W. G. Carey.*

Activated Carbon in Missouri. ANON. Public Works, **64**: 5, 36, 1933. City of Cameron takes its supply from bottom level of impounding reservoir. During summer months, tastes and odors are successfully controlled by adding mixture of activated carbon with lime by means of dry-feed machine. Application of 0.1 g.p.g. is made at cost of $1.57 per m.g. At Moberly, 1 pound of activated carbon is suspended in 50 gallons of water and mixture discharged into outlet end of settling basins. Rate of application varies from 0.04 to 0.4 g.p.g., depending upon conditions.—*C. C. Ruchhoft (Courtesy Chem. Abst.).*

Keeping Filter Sand and Gravel Clean. W. H. LOVEJOY. Water Works and Sewerage, **80**: 5, 180, 1933. Effectiveness in filter washing is influenced by

underdrain system, by amount of freeboard, by rate of wash water rise, and by particle size of filter sand. Intermittent chlorination removes organic deposits. Caustic soda is comparatively ineffective. High pressure hosing removes clay coatings. For old beds, sand washing machine is necessary.—*C. C. Ruchhoft.*

Water Softening and Purification at Columbus, O. ANON. Water Works and Sewerage, 80: 5, 182, 1933. During 1932, 98 gallons per capita were softened on average, daily, (hardness reduction 68 percent) and filtered. Costs, including lime, soda ash, alum, chlorine, and coke, averaged $10.29 per m.g. Turbidity was reduced from average of 76 to 0 and color, from 29 to 1 p.p.m. Five typhoid deaths for year included 3 resident and 2 non-resident and resulted in rates of 1.7, 1.0, and 0.7 per 100,000 respectively.—*C. C. Ruchhoft.*

Operating Conditions at Athens, Greece, Water Purification Plant. LOUIS A. GEUPEL. Water Works & Sewerage, 80: 4, 113–16, 1933. City supply includes: from old Hadrian Aqueduct, 1.6 m.g.d., from new 11-billion-gallon impounded Lake of Marathon, 1.3 m.g.d. of percolation water through 8.5-mile tunnel; and from driven artesian wells, 1.4 m.g.d. Hadrian supply is used only during dry season, when it is clear and wholesome. During rainy season all supplies are turbid and are filtered through the 18-m.g.d. plant. Treatment includes aëration, sedimentation, filtration, chloramine sterilization, and wash water recovery. Several months operation of wash water recovery show net plant waste of 0.33 percent, reckoned upon raw water treated, equivalent to annual saving of 55 m.g. At present only 50 percent of population is connected to distribution system and this partially accounts for low consumption rate of 5.5 gallons per capita per day.—*C. C. Ruchhoft.*

Water Supply for Tanneries. AUG. C. ORTHMAN. Water Works and Sewerage, 80: 4, 138–40, and 5, 163-5, 1933. Different methods of tanning and uses of water at various stages are explained. For best results, two different kinds of water should be available. For soaking, washing, and dehairing, total hardness should not exceed 30 g.p.g., nor total iron, 0.1 g.p.g.; and temperature should be constant throughout year and not greater than 60° F. For all other stages which include bating, pickling, tanning, coloring, and fat-liquoring, maximum limits are: for total hardness, 8.0 g.p.g.; for alkalinity, 7.5 g.p.g.; for iron, 0.1 g.p.g.; and causticity must be nil. Lime-soda softening process is satisfactory and zeolite softened water may be used for all operations except coloring. Quantities of water necessary vary with different plants, but figure of 6,750 cubic feet (50,625 gallons) per pack of 3300 pounds may serve as rough indication.—*C. C. Ruchhoft* (*Courtesy Chem. Abst.*).

The Water Supply of Spartanburg, S. C. R. B. SIMMS and J. K. MARQUIS. Water Works and Sewerage, 80: 5, 177-8, 1933. Construction of hollow reinforced concrete dam created impounding reservoir of 1.5-billion-gallon capacity and power head of 63 feet. Filter plant, of 1-m.g.d. capacity, is so located as to eliminate low-lift pumping and power plant furnishes all electricity needed for operation. Equipment includes complete laboratory facilities and clear

well holding 0.75 m.g. Total cost of development was $1,350,000, of which $395,000 is charged to power plant.—*C. C. Ruhhoft.*

Distribution of Mottled Enamel in the United States. H. TRENDLEY DEAN. U. S. Public Health Reports, **48**: 25, 703, June 23, 1933. This paper reports the results of a survey to determine the distribution of mottled enamel in the United States. Of the 415 questionnaires sent to the various component or local societies asking for a report on mottled enamel within the geographical boundaries of their society, 207 replied. Special points of interest by states are given. There are 97 localities where mottled enamel has been confirmed by survey. There are, in addition, 28 areas referred to in literature as mottled-enamel areas where no confirmatory surveys are reported. 70 areas have been reported by questionnaires but not confirmed by surveys. 5 areas reported by questionnaries which are held as questionable pending receipt of further data.—*A. W. Blohm.*

Reduction of Corrosion in Water Pipe. EDWARD S. HOPKINS. Ind. Eng. Chem., **25**: 9, 1050, 1933. Corrective treatment with lime has been practiced at Baltimore since 1922. A pH of 7.9 is now found satisfactory and in 1932 was maintained continuously at a cost of $0.14 per million gallons. No reduction in pH occurs throughout the system. Total hardness is increased by about 9 p.p.m., but decrease in repair bills and in damage from leaks and staining more than compensates for additional soap costs. Operating and maintenance costs for pipe lines were lower by $8.41 per mile in 1932 than in 1920.—*Selma Gottlieb.*

Manufacture of Aluminum Sulfate at the Dalecarlia Filter Plant, Washington, D. C. CARL J. LAUTER. Ind. Eng. Chem., **25**: 9, 953–8, 1933. Manufacture of aluminum sulfate sirup by HOOVER process is described. It is made in 10,000-gallon, lead-lined kettles, in 12-ton batches, and is usually diluted to contain from 7.5 percent to 15 percent of aluminum sulfate and about 1 percent of free acid. Specifications and methods for handling of bauxite, acid, and sirup, construction of equipment, and reaction process are discussed, and detailed cost analysis is presented. Over five-year period, net cost of aluminum sulfate containing 17 percent of alumina was $13.00 per ton, a saving of $5 per ton, or from $10,000 to 12,000 per year, as against commercial alum.—*Selma Gottlieb.*

Floc Formation Studies in Water Purification. AUGUST G. NOLTE and WARREN A. KRAMER. Ind. Eng. Chem., **25**: 10, 1110–2, 1933. Samples of clarified river water, pH and turbidity of which had been carefully adjusted, were treated respectively with aluminum sulfate, dry sodium aluminate, anhydrous and hydrated ferric sulfate, hydrated ferrous sulfate, and commercial ferric chloride solution. In their optimum ranges, aluminum and iron salts have about same effectiveness in turbidity removal. Less residual persists from iron than from alumina, but lowest residual does not coincide with best turbidity removal. Ferric chloride and ferrous sulfate have narrow optimum

pH ranges, but ferric sulfate, a wide one. Optimum pH for alum is higher than that for sodium aluminate.—*Selma Gottlieb.*

Mechanism of Corrosion of Iron in Sodium Chloride Solution. E. G. R. ARDAGH, R. M. B. ROOME and H. W. OWENS. Ind. Eng. Chem., **25**: 10, 1116-21, 1933. Procedure is given for obtaining reproducible measurements of potential of iron electrode in brine, absence of oxygen being essential. Electrode was first exposed to air, to produce an iron-iron oxide surface. Certain classes of organic compounds were found to inhibit corrosion of iron by 0.1 normal sodium chloride solution at pH. 7, due to adsorption of inhibitor on metal surface and not to oxide formation, as in case of chromates. The mechanism of inhibition and types of compounds producing it are discussed.—*Selma Gottlieb.*

Colorimetric Determination of Fluorine. W. D. ARMSTRONG. Ind. Eng. Chem., Anal. Ed., **5**: 5, 300–2, 1933. Fluorine is determined by its fading action or ferric acetyl-acetone in slightly acid solution. Influence of acidity and of interfering substances may be counteracted. Results are satisfactory in presence of 0.05 g. of sodium chloride, of 0.1 gm. of sodium sulfate, or of 0.4 gm. of sodium nitrate per 25 cc.; or of silicic acid up to saturation. Fluorine content of aliquot tested should be not over 0.25 mg.—*Selma Gottlieb.*

Photometric Investigation of Nessler Reaction and Witting Method for Determination of Ammonia in Sea Water. HENRY E. WIRTH and REX J. ROBINSON. Ind. Eng. Chem., Anal. Ed., **5**: 5, 293–6, 1933. In distilled water, Standard Methods NESSLER solution had shortest non-sensitive region and gave best results of 4 NESSLER reagents studied. In sea water, TREADWELL'S NESSLER reagent developed color most rapidly, had no non-sensitive region, and did not give turbidity if interfering substances were removed by WITTING method, which was found to cause no loss of ammonia by adsorption on precipitate. Sensitivity of TREADWELL reagent increased with increasing chlorinity and as little as 0.003 p.p.m. of ammonia nitrogen could be directly detected in sea water.—*Selma Gottlieb.*

Tyndallmetric Examination of Filtered Liquors. A. B. CUMMINS and M. S. BADOLLET. Ind. Eng. Chem., Anal. Ed., **5**: 5, 328–32, 1933. Photometric measurement is made of TYNDALL beam produced in filtrate by passing controlled and constant light beam into it under standard conditions. Results are expressed directly in photometric units. Apparatus consists of constant primary light source, optical systems for incident beam and for examination of TYNDALL beam, mounting for cell containing the liquid, and photometric measuring system. Measurements on water and other liquids are given.—*Selma Gottlieb.*

Silicon Tetrafluoride Volatilization. W. D. ARMSTRONG. Ind. Eng. Chem., Anal. Ed., **5**: 315–6, 1933. Highly simplified apparatus is described for quantitative volatilization of fluorine from dried samples, as silicon tetrafluoride, losses of which due to hydrolysis are prevented.—*Selma Gottlieb.*

Water of Crystallization in Total Solids of Water Analysis. V. P. SOKOLOFF. Ind. Eng. Chem., Anal. Ed., **5**: 5, 336–7, 1933. List is given of probable formulas of salts obtained when residues from evaporation of natural waters are dried at 110°C. By adding calculated water of crystallization to sum of determined constituents, latter is brought into closer agreement with total solids as determined by evaporation and accuracy of determinations can be checked.—*Selma Gottlieb.*

A Modified Eijkman Medium. C. A. PERRY and A. A. HAJNA. Jour. Bact., **26**: 4, 419–29, 1933. More *B. coli* were recovered from feces with Standard Methods lactose broth than with original EIJKMAN medium at 46°C.; but reverse was true when latter was modified by buffering with 0.4 per cent of di-potassium hydrogen phosphate and using 0.3 per cent of glucose instead of 1.4 per cent. *B. coli* cultures in old medium were seldom viable after 24 hours incubation at 46°C.; but in new medium all were viable 118 hours or longer. Tests showed that ability to ferment glucose at 46°C. is fundamental characteristic of *B. coli*, as stated by EIJKMAN. Authors construe *B. coli* to include only those members of coli-aerogenes group which invariably ferment glucose at 46°C. in suitable medium and are unable to utilize citrate carbon. Importance of EIJKMAN test in water analysis is stressed.—*Selma Gottlieb.*

Development and Control of Microorganisms in a Pulp and Paper Mill System. J. R. SANBORN. Jour. Bact., **26**: 4, 373–8, 1933. Organisms contributing to slime formation include various species of bacteria, yeasts, molds, and algalike bacteria. Process water and stock were examined bacteriologically at significant stages in the plant to determine distribution of organisms, points of inoculation, and effectiveness of methods of control. Chemical treatment, which includes use of chlorine, ammonia-chlorine, and copper salts, must be supplemented by scraping, hosing, etc. with alkali, to remove deposits not penetrated by the chemicals.—*Selma Gottlieb.*

Application of Statistics to Problems in Bacteriology. II. A Consideration of the Accuracy of Dilution Data Obtained by Using a Single Dilution. H. O. HALVORSON and N. R. ZIEGLER. Jour. Bact., **26**: 4, 331–9, 1933. From mathematical considerations it is shown that in determining bacterial population by dilution method, it is not possible to establish definitely the accuracy of data obtained from a single dilution without a priori knowledge of the population. This limitation can be largely overcome by using several dilutions, a procedure whose accuracy will be discussed in a later paper.—*Selma Gottlieb.*

NEW BOOKS

Journal North Carolina Section, A. W. W. A. 10: 1, 1932. 68 pp. **Office Practice in the Winston-Salem Water and Sewer Department.** R. L. DIXON. 1-11. Consolidation of billing and collection of Water Department with Department of Public Works has resulted in increased efficiency and reduced expenses. New system has been installed. Old and new systems are described

and compared. **Metering at Durham.** D. M. WILLIAMS. 12–14. From time when water falls as rain, until it enters consumers' premises, it is measured, excepting only that furnished for fire protection. Five rainfall stations are maintained on watershed and two at plants. Well-gaging station measures ground water storage. Four stream-gaging stations measure water entering Lake Michie, a fifth recording that which passes down stream below the dam. A gage records water level in lake; another, the evaporation proceeding therefrom. Venturi meters measure pumpage to filtration plant, where water is metered before entering coagulating basins and again as it is pumped into distribution mains. Consumers' services are 100 per cent metered. All 1½-inch meters and larger are read each week; all others, quarterly. **Rate Making.** J. H. BRIDGES. 15–18. In North Carolina where water works are almost entirely municipally owned, fixed items of cost include: (1) debt service, (2) debt payment, (3) replacement and inadequacy, and (4) administration: items which vary with consumption include: (1) pumping, (2) filtration, (3) distribution service to customers, and (4) meter maintenance. For rate-making purposes, consumers are classified into domestic, commercial, and wholesale. Fire hydrant rentals should be sufficient to pay for the service. Meter plant should be at least ninety-five per cent perfect and all meters should be rebuilt on average every five years. **Water and Sewage Treatment Progress on the Pacific Coast.** HARRY N. JENKS. 19–26. Water supplies of Washington and Oregon, derived chiefly from mountains, are generally abundant, soft, and free from tastes and odors, but subject to discoloration by vegetation and to turbidity from glacial silt. Changes detrimentally affecting natural conditions are beginning to focus attention on water purification. Industries are demanding higher standards of water quality. Practically all public supplies on Pacific Coast are at least chlorinated. California surface waters are hard, as compared with those of the Northwest, but relatively free from color; turbidity is less colloidal and more amenable to treatment; tastes and odors, except those due to industrial wastes, are seldom present. Value of water treatment in California is now fully established. Economy and practicability of purifying available nearby supplies is being more fully recognized. Tastes have occurred in supplies from wells. Receding water table has increased pumping cost and is regarded as indicating future shortage in Southern California wells. It is the rule to chlorinate well water used for domestic supply. Southern California underground waters are definitely in need of softening as well as of color and iron removal. In spite of probable cost of $90.00 per m.g., Colorado River appears the only source in sight adequate to satisfy demand created by phenomenal growth of Southern California. Industrial waste is more important factor than domestic sewage in pollution of streams of Washington and Oregon. This region is just becoming sewage conscious. Problems of sewage disposal claimed earlier attention and have been studied and solved to a greater extent and with more success in California, where present day plants, being designed to meet specific local conditions, assume great diversity of form, of combinations of methods, and of plant layout. Water is at a premium in most of thickly-settled parts of this state and it becomes economically advantageous to carry sewage treatment to such a point as will permit effluent to be used for irrigation, if not for industrial purposes. Some

Methods of Obtaining Technical Control of Treatment Works. D. S. ABELL. 26–30. Much work has been done in North Carolina along this line through: (1) early enactment of water supply laws, (2) active state sanitary engineering service, (3) public health engineering courses at two major educational institutions, and (4) effective Section of American Water Works Association. In order to secure permanency of capable personnel and to provide additional technical control, following possibilities are offered for consideration: (1) licensing of plant operators, (2) one-man technical supervision of group of plants, (3) expanding duties of plant operators into allied technical municipal activities, and (4) establishment of short schools. **Opportunities for Research in the Operation of Water Purification Works.** M. F. TRICE. 31–35. Each plant offers its own peculiar problems. Several specific suggestions for local study are made. There is widespread need for study of raw waters, of coagulating process, of care of filters, and of quality of finished waters, especially to meet exacting industrial demands. **Improved Coagulation at the Richmond, Virginia, Filter Plant.** MARSDEN C. SMITH. 36–43. Description of mechanical devices to effect coagulation after mixing immediately after addition of coagulants, consisting of paddles on horizontal shafts connected to variable speed motors. Settled floc is continuously removed and the return of a portion of it is a feature of this system. Coagulation costs have been greatly lowered and filter effluent improved. **The Dearborn, Michigan, Sewage Treatment Plant and Its Operating Results.** MARK B. OWEN. 44–68. Peculiar problems presented and expedients by which they have been met are described.—*W. H. Weir.*

Metropolitan Water Board (London) 27th Chemical and Bacteriological Report for Year Ending December 31st 1931. SIR A. HOUSTON. 35 pp. and illustrations. Average daily water consumption was 281.4 million gallons. Routine samples examined numbered 17,611, in addition to large number for special purposes. Cases of enteric fever numbered 195; in 1900 they were 4,292. Chlorination of Thames river water is dealt with, all chlorination being after filtration except when unfiltered raw water is passed down Staines aqueduct. With chlorine dose of 0.2 to 0.3 parts per million and ammonia usually of 0.12 parts per million, Kempton Park water gave 100 percent freedom from *B. coli* in 100 cc., West Middlesex, with 96.4 per cent, making least favourable showing. Examination of pre-filtered waters, as raw, as stored, and as rough-filtered through gravel, evidences certain chemical and physical changes consequent upon storage, and bacteriological improvement in most cases of 100 to 1,000-fold as judged by *B coli* test. At Walton, raw water is stored, filtered without coagulation through primary rapid filters, and again through slow sand filters at much higher speed than is customary, and finally treated first with ammonia and then with chlorine. Storage effects reduction in free and albuminoid ammonia, oxygen absorbed, and color, while finally treated water yielded 97.5 percent first class samples. At Kempton Park works, bacteria are reduced 94.5 percent by storage and after filtration through primary and secondary filters, but before chlorination, 84.0 percent of samples showed no *B. coli* in 100 cc., probably attributable to fineness of sand, although rate of filtration in secondary filters was 3.73 gallons per square foot per hour. Question of finer sand

and faster filtration *v.* coarser sand and slower filtration merits further study. Resistance to filtration and microscopical appearance of pre-filtration waters is dealt with, as well as *B. coli*-cum-Streptococcus test, by which within three days number of fecal Streptococci can be estimated, using McConkey tubes employed for *B. coli*. Streptococcus test may, with greater knowledge, differentiate human pollution from that of birds or lower animals. Résumé of work done in connection with Epping paratyphoid outbreak in 1931 is given, with number and sequence of cases, and consideration of expectation of finding paratyphoid bacteria in ordinary samples of sewage and effluent. Experience of ozone treatment is given, and result of study of green colonies on Wilson and Blair's medium.—*W. G. Carey.*

Sanitation and Water Purification A. Parker. Reports of the progress of applied chemistry (issued by Society of Chemical Industry, London) **17**: 1932, 626–662. Survey of world progress during 1932 in water purification, sewage treatment, trade waste water treatment, river pollution control, and atmospheric pollution prevention. Dealing with water, author mentions outbreaks of typhoid at Malton and Denby Dale and of paratyphoid at Epping, such outbreaks having undoubtedly further encouraged in England inclusion of disinfection as part of treatment of public water supplies. Developments in chlorination and in ammonia-chlorine treatment are described, experience in Ontario, Indianapolis, Cleveland, Defiance, Danville, and Los Angeles being quoted. Treatment with excess lime, ozone, ultra-violet light, oligodynamic materials, activated carbon, and electro-osmosis are dealt with, as also sterilization of new mains, cooling water, etc. with chlorine, as practised in New York, Milwaukee, and other places. Effects of iodine and fluorine in water are considered, concensus being that goitre is prevalent when iodine is deficient in water and food. Increased attention is being given to study of factors influencing corrosive and plumbo-solvent action of water; but author considers that much investigation is still necessary as well as further information as to best methods of treatment. Filtration through calcined magnesite is said to possess advantages over treatment with limestone chippings, lime, caustic soda, or soda ash. Ternary alloys of lead are metioned. Purification of swimming pool water by coagulation, filtration, and chlorination is being more extensively practised, for sea-water as well as for fresh water baths. Investigations of certain properties of base-exchange materials are considered, and methods of treatment of feed water by addition of sodium sulphate, sodium phosphate, or sodium or barium aluminate, are mentioned.—*W. G. Carey.*

Report of the Water Pollution Research Board (England) for the Year Ending 30, June, 1932. 55 pp. Since September 1929 there has been no abnormally dry period in England and consequently outstanding cases of exceptional pollution or of water shortage have been fewer. General industrial depression has caused reduction in trade effluents; but has retarded progress of investigations. Inoculation of semi-commercial size percolation filter with organisms capable of oxidizing sugar from beet-sugar wastes increased only slightly percentage of purification. Preliminary experiments with dairy wastes have been made, particularly on 5-day B.O.D. To secure adequate aëration filter is being

used built below in sections containing gravel, and with wood lath construction on top. Survey of River Tees shows that neither oxygen deficiency, nor tar acid from coke ovens, was sufficient to account for high salmon mortality; but that cyanide was frequently present in lethal concentrations. Reduction of cyanide can be effected by intimately mixing cyanide effluent in presence of lime with spent pickle liquid (strong solution of ferrous chloride), or by spraying effluent as fine mist at about 60°C. Preliminary experiments have been begun to study rate of attack on lead by different waters, noting influence of method used to clean lead on its subsequent behavior, and effects of electric power leakage on lead water pipes. In base exchange water softeners when single stage regeneration is used, base exchange values of typical materials rise progressively as time of contact with regenerating 5 percent salt solution is increased from 2 to 90 minutes. Quantity of water softened by given amount of base material without regeneration decreases rapidly as concentration of salt in hard water is raised from 0 to 1 percent.—*W. G. Carey.*